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EXPERIMENTAL TOURNIQUET SHOCK WITH PARTICULAR REFERENCE TO THE TOXIC FACTOR

A METHOD OF PRODUCTION ELIMINATING THE INFLUENCE OF GENERAL ANESTHESIA AND NERVOUS IMPULSES

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In any experimental study of shock, simplicity and uniformity of production are admittedly essential factors. We agree with Allen [1] and Moon [2] that the tourniquet technic probably meets these requirements more easily than any other method, such as trauma to a hindlimb, burning, intestinal manipulation or hemorrhage. Nevertheless, the serious criticisms of the influence of anesthesia and of nervous impulses in the production of experimental shock have been applicable to practically all tourniquet methods heretofore used. It seemed desirable in our study of the problem to overcome these objections as much as possible before attempting to gather evidence either for or against any of the three currently accepted theories as to the cause of shock: (*a*) local loss of circulating fluid (Blalock and Duncan,[3] Parsons and Phemister,[4] Wilson and Roome [5] and Mann and Mann and Essex [6]); (*b*) absorption of a toxic substance from injured areas (Dale and Laidlaw and Dale, Laidlaw and Richards,[7] Cannon and Bayliss and Cannon,[8] Green and Green and Bielschowsky [9] and Scudder [10]); (*c*) effect of nervous impulses (Phemister and associates,[11] Crile and Lower,[12] Cooper,[13] Simonart,[14] O'Shaughnessy

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2. Moon, V. H.: Shock: Its Dynamics, Occurrence and Management, Philadelphia, Lea & Febiger, 1942.

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8. Cannon, W. B.: A Consideration of Possible Toxic and Nervous Factors in the Production of Traumatic Shock, Ann. Surg. **100**:704, 1934. Bayliss, W. M., and Cannon, W. B.: Note on Muscle Injury in Relation to Shock, in Reports of the Special Investigation Committee on Surgical Shock and Allied Conditions: VIII. Traumatic Toxaemia as a Factor in Shock, Medical Research Committee, Special Report Series, no. 26, London, His Majesty's Stationery Office, 1919.

9. Green, H. N.: Shock-Producing Factor(s) from Striated Muscle: I. Isolation and Biological Properties, Lancet **2**:147, 1943. Bielschowsky, M., and Green, H. N.: Shock-Producing Factor (s) from Striated Muscle: II. Fractionation, Chemical Properties and Effective Doses, ibid. **2**:153, 1943.

10. Scudder, J.: Shock: Blood Studies as a Guide to Therapy, Philadelphia, J. B. Lippincott Company, 1940.

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12. Crile, G., and Lower, W. E.: Surgical Shock and the Shockless Operation Through Anoci Association, Philadelphia, W. B. Saunders Company, 1920.

(Footnotes continued on next page)

and Slome [15] and Freedman and Kabat [16]). Because of its simplicity and uniformity, the tourniquet method of producing shock is highly desirable, but it requires prolonged anesthesia, for dogs sometimes as long as twenty-four hours, to overcome the severe pain produced by the tourniquet while the experiments are being done. Often, anesthesia of such duration alone is sufficient to kill a dog. It was found practicable to produce severe shock in dogs by modifying the tourniquet method and eliminating the influences of anesthesia and nervous impulses. A description of the method follows.

METHODS AND RESULTS

Production of Shock.—With the animals under anesthesia induced by intraperitoneally administered pentobarbital sodium (32 mg. per kilogram of body weight), the spinal cord was completely divided between the thoracic and the lumbar region in a series of 10 dogs. By the second day the dogs were recovered sufficiently to take food and water. On the third or fourth day the hair was clipped and shaved over the left hip and the area scrubbed gently with 70 per cent alcohol. A square of gauze moistened with alcohol was placed over the area, its center being directly over the femoral trochanter, which is subcutaneous at that point. A thin sterile nail about 2½ to 3 inches (6 to 8 cm.) long, with its tip filed to a sharp point, was driven with a hammer through the gauze into the trochanter, the nail pointing distally and oblique to the shaft of the femur. Two to three turns of thin rubber tubing, such as is used for intravenous infusions, were wound tightly around the thigh at the groin above the nail, which prevented the tourniquet from slipping out of place; the ends of the tourniquet were tied together with cord. Previous section of the spinal cord obviated the necessity of anesthesia during or subsequent to this procedure. The tourniquet was sufficient to shut off all circulation to the hindlimb, so that no appreciable swelling occurred while the tourniquet was in place except in 1 or 2 instances. In these cases there might possibly have been some flow of blood through the femur or damage to perforating arteries in the femur by the nail in the interval before the tourniquet could be applied, since it seemed that in 1 case at least the leg was swollen immediately after the tourniquet was applied, and at postmortem examination a blood clot was found beneath the skin. Ischemia of the hindlimb was maintained for from nine to twenty hours, after which the tourniquet was released. The dogs then rapidly entered into a state of shock, and all died. No evidence of infection was noted in the limb at the site of the puncture made by the nail. Blood pressure was determined before and periodically after release of the tourniquet in the femoral artery of the right hindlimb, by the intra-arterial sphygmomanometer method [17]; blood samples were simultaneously taken for determinations of specific gravity (the falling drop method), hematocrit value and pyruvic acid. Changes in the rectal temperature were also recorded.

Much effort has been expended in experimental work on shock to determine pathognomonic signs, but at the present time it is generally agreed that the only sign that is common to all types is a sustained fall in blood pressure.[18] Other signs, such as hemoconcentration, increase or decrease in specific gravity of the serum, rise or fall in body temperature and tachycardia, vary with the type of shock. After application of the tourniquet and up to the time of its release the dogs appeared to be normal, except, of course, for paralysis of the lower part of the body and its effects, such as urinary and fecal incontinence. They appeared to be alert; they took food and water, and their respiratory rate, pulse rate and blood pressure were within normal limits. Just prior to the release of the tourniquet, the blood pressure was taken and was found to range between 90 and 120 systolic in the 10 dogs of this series. These figures compare well with those reported as normal (90 to 120) by Parkins,[17] in a study of the normal blood pressure in dogs, determined by the intra-arterial needle puncture method.

Although the manifestations of tourniquet shock in dogs have been reported previously, our findings will be listed, at least in slight detail, to indicate that section of the spinal cord did not alter significantly the development and the type of shock following release of the tourniquet. After release of the tourniquet all dogs immediately became restless. Within ten or fifteen minutes, the blood pressure fell 10 to 20 mm. of mercury and then rose, but in the animals of this series it never reached the normal value, which was determined for each dog just prior to release of the tourniquet. Then there was a gradual fall until death occurred, on an average two to two and one-half hours after release of the tourniquet. Usually within an hour the dog was noticeably lethargic and began to exhibit muscular twitchings in various parts of the body. However, the dog remained responsive until at least one-half hour before death, and lid reflexes were present almost to the point of death. The pulse, which before release of the tourniquet was strong and full, with a rate of 80 per minute, soon

13. Cooper, A.: The Principles and Practice of Surgery, Philadelphia, Cary and Hart, 1835.

14. Simonart, A.: Etude experimentale sur la toxemie: Traumatique et la toxemie des grands brules, Arch. internat. de pharmacodyn. et de therap. **37**:269, 1930.

15. O'Shaughnessy, L., and Slome, D.: Etiology of Traumatic Shock, Brit. J. Surg. **22**:589, 1935.

16. Freedman, A. M., and Kabat, H.: The Pressor Response to Adrenalin in the Course of Traumatic Shock, Am. J. Physiol. **130**:620, 1940.

17. Parkins, W. M.: Observations on Direct Intra-Arterial Determination of Blood Pressure in Trained Unanesthetized Dogs, Am. J. Physiol. **107**:518, 1934.

18. Evans, E. I.; Hoover, M. J.; James, G. W., and Alm, I.: Studies on Traumatic Shock: I. Blood Volume Changes in Traumatic Shock, Ann. Surg. **119**: 64, 1944.

became rapid after release of the tourniquet and gradually became weaker, thready and more rapid, until it was practically impalpable one-half hour before death, when the rate was usually about 140 per minute or more. To obtain blood pressure readings when the pulse was impalpable, it was our policy to cut down on the femoral artery in the thigh and insert the needle under direct vision. Respiration, which was normal to begin with, became noticeably more rapid immediately after release of the tourniquet. It showed a tendency to return to normal and then gradually became more rapid and more shallow, until just before death breathing was deep and gasping, with retraction of the trachea. The heart may continue beating after respiration has ceased. Hematocrit determinations usually showed progressive increase in packed cell volume, while the specific gravity of the serum, as a rule, decreased (table).

The pyruvic acid level of the blood showed no significant change. The girth of the leg before and after release of the tourniquet was measured 2 inches (5 cm.) above the knee; the average increase in circumference measured about 0.5 cm. Comparative weights of the two hindlimbs, determined by a method to be described, averaged 21 Gm. per kilogram increase of body weight. Therefore, the average gain in weight in the constricted extremity represented 2.1 per cent of the body weight. Occasionally a dog had a hemorrhagic bowel movement just before death and spontaneously expelled a concentrated urine. Rectal temperatures showed a slight rise of 0.5 to 1 F. from the time of release of the tourniquet until death. Gross and microscopic observations at necropsy agreed with observations recently reported (Moon,[2] Blalock and Duncan[3]). The spleen was contracted, the liver, lungs and kidneys congested and the adrenal glands and the large bowel hemorrhagic. The data on these experiments are shown in the table.

EXPERIMENTS RELATED TO THE PATHOGENESIS OF TOURNIQUET SHOCK (TESTING FOR TOXINS BY CROSS TRANSFUSION)

As will be discussed later, the amount of plasma lost into the dog's hindlimb after application and release of the tourniquet was only 2.1 per cent of the body weight. Since this amount is not considered sufficient to account for death on that basis alone, we decided to investigate the possibility of toxemia as a cause of death. Lymph collected from the thoracic ducts of animals suffering from crush injury has already been found to be toxic (Blalock[19]). From a study of blood which had been removed from a dog dying from tourniquet shock it appeared to us that blood drawn from the general circulation would be too dilute to demonstrate toxicity. We therefore adopted methods to test the blood removed directly from the femoral vein draining the leg from which the tourniquet had been released.

These experiments, though entirely of a preliminary character, are reported now because exigencies of war have prevented their completion.

EXPERIMENT 1.—The spinal cord of each of 2 dogs was cut at the level of the lowest dorsal vertebra. After a lapse of three days for recovery from the chordotomy, 1 dog was given 5 mg. of heparin per kilogram of body weight, and a tourniquet was applied for sixteen hours. Cannulas were then inserted into the femoral vein above the tourniquet in both directions. After a similar dose of heparin was given to the other (control) dog, cannulas were placed in a femoral vein, one in each direction, and the tubes connected so that a cross transfusion could be performed from the limb to which the tourniquet had been applied to the limb of the control dog. The tourniquet was then released and cross circulation established between the 2 dogs. The blood pressure was 98 for the dog which had been subjected to application of the tourniquet and 90 for the other dog at the beginning of the transfusion. After fifty minutes the pressure was relatively unchanged but the rate of flow had decreased, perhaps because of partial clotting. With a syringe blood was then withdrawn from 1 animal and injected into the other. Only about 50 cc. had been interchanged by this method before the dog to which the tourniquet had been applied showed serious evidence of shock. It died one hour and fifty seconds after release of the tourniquet. The dog which received blood from the shocked dog died two hours and thirty seconds after the cross transfusion was started. Inability to determine just how much blood was interchanged is undesirable, even though a blood pressure of 90 for each animal before transfer of an equal quantity (measured by syringe) of blood is fairly good evidence that the shock in neither dog was due to loss of blood. Nevertheless, it was decided that in additional experiments the amount of blood transferred from 1 dog to another must be accurately measured.

EXPERIMENT 2.—Two dogs were prepared, as described previously, by chordotomy, from which they recovered. A tourniquet was applied to the hindlimb of 1 and left in place for sixteen hours. The femoral vein was cannulated above the tourniquet, which was then released, and the blood was collected in a sterile bottle, until the dog died two hours and ten minutes later. Approximately 800 cc. of blood was collected, while the dog was being given transfusions of the same amount of compatible heparin-treated blood through a superficial vein in the opposite hindlimb. The blood was stored overnight in a refrigerator, and the plasma, which amounted to 430 cc., was siphoned into a sterile vacuum bottle. It was given to a normal dog (whose blood was found to be compatible by blood-grouping and

19. Blalock, A.: A Study of Thoracic Duct Lymph in Experimental Crush Injury and Injury Produced by Gross Trauma, Bull. Johns Hopkins Hosp. **72**:54, 1943.

Data Illustrating Experimental Tourniquet Shock in Dogs Under Anesthesia Achieved by Section of the Cord *

Dog No.	Sign	Before Release of Tourniquet	10 to 15 Min.	30 Min.	1 Hr.	1 Hr. and 30 Min.	2 Hr.	2 Hr. and 30 Min.	3 Hr.	At Death	Survival After Release of Tourniquet	Dog Weight, Kg.	Weight Gain of Constricted Extremity, Gm.	Percentage of Weight Gain
1	Blood pressure	120	....	80	54	..	38	20	..	0	2 hr. and 35 min.	14.5	255.1	1.75
	Hematocrit reading	52	....	..	58	..	63	..	..	66				
	Specific gravity	1.0261	....	..	1.0260	..	1.0254	..	..	1.0251				
	Rectal temperature	104	....	..	104	..	104.2	..	..	104				
	Pyruvic acid, mg. %	0.45	....	..	..	..	..	..	..	0.475				
2	Blood pressure	100	70	74	60	40	30	..	..	0	2 hr.	10.9	226.8	2.07
	Hematocrit reading	53	....	..	57	..	..	..	..	62				
	Specific gravity	1.0250	....	..	1.0244	..	..	..	..	1.0238				
	Rectal temperature	103	....	..	103	..	..	..	..	103.4				
	Pyruvic acid, mg. %	0.60	....	..	..	..	..	..	..	0.62				
3	Blood pressure	105	76	84	110	65	78	65	50-40	0	3 hr. and 30 min.	11.9	283.5	2.37
	Hematocrit reading	53	....	..	55	..	..	58	..	62				
	Specific gravity	1.0248	....	..	1.0244	..	..	1.0240	..	1.0238				
	Rectal temperature	103.5	....	..	103	..	..	103	..	102				
	Pyruvic acid, mg. %	0.10	....	..	..	..	..	..	..	0.15				
4	Blood pressure	110	72	80	70	55	40	..	..	0	2 hr. and 25 min.	11.4	226.8	1.98
	Hematocrit reading	40	....	..	43	..	..	..	..	45				
	Specific gravity	1.0255	....	..	1.0248	..	..	..	..	1.0241				
	Rectal temperature	103.8	....	..	104	..	..	..	..	104				
	Pyruvic acid, mg. %	0.25	....	..	..	..	..	..	..	0.275				
5	Blood pressure	130	70	80	75	48	40	..	..	0	2 hr. and 20 min.	11.4	453.6	3.97
	Hematocrit reading	62	....	..	64	..	65	..	..	67				
	Specific gravity	1.0257	....	..	..	..	1.0276	..	..	1.0274				
	Rectal temperature	104	....	..	104	..	104.2	..	..	104.2				
	Pyruvic acid, mg. %	0.40	....	..	..	..	..	..	..	0.43				
6	Blood pressure	95	68	70	50	35	30	..	..	0	2 hr. and 10 min.	11.9	226.8	1.90
	Hematocrit reading	51	....	..	55	..	..	..	..	58				
	Specific gravity	1.0291	....	..	1.0281	..	..	..	..	1.0280				
	Rectal temperature	102.4	....	..	102.6	..	..	..	..	103				
	Pyruvic acid, mg. %	0.55	....	..	..	..	..	..	..	0.57				
7	Blood pressure	130	90	96	90	80-50	..	..	..	0	1 hr. and 50 min.	13.7	255.1	1.85
	Hematocrit reading	57	....	..	75	..	..	..	..	78				
	Specific gravity	1.0251	....	..	1.0275	..	..	..	..	1.0247				
	Rectal temperature	103	....	..	102.2	103	103	..	..	103.6				
	Pyruvic acid, mg. %	0.215	....	..	..	..	..	..	..	0.275				
8	Blood pressure	128	100	50	45	40	40	25	..	0	2 hr. and 45 min.	16	283.5	1.77
	Hematocrit reading	54	....	62	..	66	..	..	..	..				
	Specific gravity	1.0248	....	1.0251	..	1.0241	..	1.0223	..	..				
	Rectal temperature	104.3	104.3	104.5	105	..	104	..	..	104.5				
	Pyruvic acid, mg. %	0.25	....	..	..	..	..	..	..	0.35				
9	Blood pressure	90	70	75	60	45	25	28	..	0	2 hr. and 33 min.	12.8	283.5	2.21
	Hematocrit reading	60	....	..	63	..	60	..	..	64				
	Specific gravity	1,0223	....	..	1.0236	..	1.0228	..	..	1.0228				
	Rectal temperature	104	....	104	104.2	104.8	..	..	..	104.8				
	Pyruvic acid, mg. %	0.13	....	..	..	..	..	..	..	0.39				
10	Blood pressure	110	110	100	90	85	80	55	38-20	0	3 hr. and 35 min.	14.5	212.6	1.46
	Hematocrit reading	47	....	..	49	..	48	..	48	49				
	Specific gravity	1.0240	....	..	1.0238	..	1.0235	..	1.0233	1.0245				
	Rectal temperature	103.6	....	..	103.2	..	103.2	..	102.5	102.5				
	Pyruvic acid, mg. %	0.15	....	..	..	..	..	..	..	0.24				
										Average	2 hr. and 34 min.	12.9	267.8	2.1

* These experiments were conducted at room temperature. The tourniquet was left in place at least nine hours so that the outcome would be consistently fatal following release of tourniquet.

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shock and hematocrit readings fully as high as those which occur with the severest form of shock can be obtained with such procedures as intraperitoneal injection of dextrose without leading to a fatal issue.[21] This would indicate the presence of another factor in the causation of certain types of shock, although it is obvious that frequently, indeed, loss of plasma alone is sufficient to cause death. Death from tourniquet shock could be explained on the basis of a widely distributed toxin arising from the ischemic limb and acting on the vital organs, with lethal results. Blalock [19] has already shown that the lymph draining from a crushed limb (experimental observation) is toxic. The similarity between the pathologic systemic effects of a crushed limb and an ischemic limb is apparent but by no means absolute.

After the report of Govier and Greer [22] on the prolongation of survival time by administration of thiamine hydrochloride to dogs shocked by repeated hemorrhages, it might appear that a pyruvic acid compound which Peters and Peters and Long [23] have shown is an especially important carbohydrate catabolite of nerve tissue would be important in the pathogenesis of shock itself; hence the reason for determining the pyruvic acid blood levels periodically during the course of shock. However, no significant alteration in the pyruvic acid content of the blood was noted.

In a few preliminary studies in which the tourniquet was left in place for less than nine hours some of the dogs recovered. The constriction was thereafter always maintained for longer than nine hours. Wilson and Roome [5] obtained death in 100 per cent of their animals after constriction for more than six hours; Swingle and associates [21] reported that 96 per cent of their animals subjected to constriction for five hours died in shock. These investigators used a slightly different method of keeping the tourniquet in place, but all of them employed anesthesia produced with barbital compounds for long periods of time. Fat dogs seemed to survive longer after release of the tourniquet than dogs of average weight. The length of time over nine hours that the tourniquet remained in place did not seem to bear any relationship to the rapidity with which shock and death resulted after release of the tourniquet. The survival time following release of the tourniquet averaged two hours and thirty-four minutes and varied between two and four hours. Seldom did thrombosis of the vessels of the leg occur, though they were constricted for as long as nine to twenty-four hours.

It is difficult to correlate the results of our experiments (i. e., production of tourniquet shock in animals which had preliminary section of the spinal cord for anesthesia) with the results of experiments of Freedman and Kabat,[16] who traumatized the hindlegs of cats to produce shock and came to the conclusion that shock was effectively prevented in such experiments by preliminary section of the spinal cord at the level of the uppermost lumbar vertebra. In our experiments release of the tourniquet after it had been in place for nine hours or more invariably resulted in death, even though our animals had had preliminary section of the cord. The only explanation would be that there is possibly a greater difference in the pathogenesis of the two types of shock (i. e. tourniquet and crush) than is supposed.

The statement of Allen,[1] that the most intensive and rapidly fatal shock (produced by the tourniquet method) is accompanied by the least local exudation, has been corroborated by others. In the present series of animals the increase in weight of the ischemic extremity after death (resulting from release of the tourniquet), as determined by the method (described by Blalock [20]) of sectioning the body through the lower part of the back and comparing the weights of the two sides, was 2.1 per cent of the body weight.

From the reports of others on the amount of loss of plasma required to produce death in animals, it is obvious that the loss, amounting to 2.1 per cent of the body weight, into the ischemic extremity in our experiments is insufficient in itself to cause death. For example, in some experiments dealing with the amount of loss of blood required to produce death, Johnson and Blalock [24] found that "the average loss of fluid that produced death, expressed in per-

21. Swingle, W. W.; Remington, J. W.; Kleinberg, W.; Drill, V. A., and Eversole, W. J.: An Experimental Study of the Tourniquet as a Method for Inducing Circulatory Failure in Dogs, Am. J. Physiol. **138**: 156, 1942.

22. Govier, W. M., and Greer, C. M.: Studies on Shock Induced by Hemorrhage: I. Effect of Thiamin on Survival Time, J. Pharmacol. & Exper. Therap. **72**:317, 1941; II. Effect of Thiamin on Disturbances of Carbohydrate Metabolism, ibid. **72**:321, 1941; III. The Correlation of Plasma Thiamin Content with Resistance to Shock in Dogs, ibid. **77**:40, 1943.

23. Peters, R. A.: The Biochemical Lesion in Vitamin B_1 Deficiency: Application of Modern Biochemical Analysis in Its Diagnosis, Lancet **1**:1161, 1936. Long, C., and Peters, R. A.: Pyruvate Oxidation in Brain: Evidence Derived from Metabolism of α-ketobutyric Acid, Biochem. J. **33**:759, 1939.

24. Johnson, G. S., and Blalock, A.: Experimental Shock: IX. A Study of Effects of the Loss of Whole Blood, of Blood Plasma and of Red Blood Cells, Arch. Surg. **22**:626 (April) 1931.

centages of body weight, was 3.2 per cent plasma and 0.85 per cent whole blood or a total of 4.05 per cent." In their experiments the average interval between the first bleeding and death was six hours and thirty-four minutes.

Since we found that in shock produced by ischemia of the hindlimb the nervous factor did not play a primary role and that in most cases the local loss of circulating fluid was also insufficient to explain shock and death, the next most plausible explanation appeared to be toxemia.

Role of Toxins in Production of Tourniquet Shock, as Revealed by Cross Transfusion.—After a review of the literature on this phase of the work, experiments were designed to test this hypothesis. Much work has been done along this line, but apparently valid criticisms can be brought against much of it. It is not our purpose here to review the literature, which has been reviewed well by others (Moon,[2] Blalock,[3] Wiggers,[25] Scudder[10]); we intend only to comment on a few experiments which have a direct bearing on our own. Ebbecke[26] showed that cytoplasmic substance, released from cells as a result either of functional activity or of any kind of irritation to the cells, causes dilatation of adjacent capillaries; moreover, the response of endothelium to cytoplasmic substance, to metabolic substance and to metabolic products is like that resulting from lack of oxygen. Green and associates[9] have isolated a substance in normal muscle which produces shock and death in small animals. Griffith[27] has obtained a toxic substance from lymph collected from a burned area, and, as stated previously, Blalock[19] has recently found a substance in the lymph of the thoracic duct of dogs with traumatized hindlimbs which is capable of causing death when injected into a normal dog. Dragstedt and Mead,[28] Kendrick, Essex and Helmholz,[29] Best and Solandt[30] and Coonse and associates[31] have all obtained substances with hypotensive properties from injured or ischemic tissues.[32] However, Wilson and Roome[5] concluded that extracts from traumatized limbs cause a rise in blood pressure. Numerous investigators have tested the toxicity of blood returning from traumatized and ischemic areas, but few or none have offered proof of the existence of a lethal toxin. True enough, in most instances the amount of blood injected into the normal animal has been insufficient.

Bell, Clark and Cuthbertson[33] performed 6 experiments on cross circulation in dogs in which they connected the femoral vein of a traumatized limb to that of a recipient. Death occurred in seventy-five minutes in the donor, and then the recipients were destroyed. The sixth recipient was not destroyed but lived ten and one-half hours. They stated that the dog died from edema of the lungs.

Owing to certain circumstances we were unable to complete the series of experiments on cross circulation; only 5 were performed. However, in these preliminary experiments evidence accumulated to lead us to the belief that blood returning from an extremity subjected to application of a tourniquet for from nine to sixteen hours is toxic to other dogs. Although all experiments were designed to test the venous blood from the constricted limb for toxins, certain variations were adopted to rule out as much as possible error from coincidence. However, all 5 experiments were conducted so that the blood transfused from the dog to which the tourniquet had been applied to the control animal came from the femoral vein draining blood from the extremity after release of the tourniquet. In 4 of the 5 animals transfusion was begun immediately after release of the tourniquet, so that none of the blood draining through the femoral vein escaped into the circulation of the shocked dog after release of the tourniquet. All 4 of the control dogs receiving blood collected from the femoral vein of the constricted limb died of shock identical to the type which killed the dog to which the tourniquet had been applied. The duration of life varied from two hours and twenty minutes to twelve hours. In the fifth

25. Wiggers, C. J.: The Present Status of the Shock Problem, Physiol. Rev. **22**:74, 1942.

26. Ebbecke, cited by Moon.[2]

27. Griffith: Unpublished data; personal communication to Blalock.

28. Dragstedt, C. A., and Mead, F. B.: A Pharmacologic Study of the Toxemia Theory of Surgical Shock, J. A. M. A. **108**:95 (Jan. 9) 1937.

29. Kendrick, D. B.; Essex, H. E., and Helmholz, H. F.: An Investigation of Traumatic Shock Bearing on the Toxemia Theory, Surgery **7**:753, 1935.

30. Best, C. H., and Solandt, D. Y.: Studies in Experimental Shock, Canad. M. A. J. **43**:206, 1940.

31. Coonse, G. K.; Foissie, P. S.; Robertson, H. F.; and Aufranc, O. E.: Traumatic and Hemorrhagic Shock: Experimental and Clinical Study, New England J. Med. **212**:647, 1935.

32. Since this article was prepared for publication, Prinzmetal, Freed and Kruger (Pathogenesis and Treatment of Shock, War Med. **5**:74 [Feb.] 1944) have demonstrated development and fatal absorption of a toxin arising from bacterial action in crushed muscle (in dogs). Also Aub and others (Bacteria and the "Toxic Factor" in Shock, ibid. **5**:71 [Feb.] 1944) reported demonstration of a shock-producing toxin, likewise of bacterial origin, in anoxic muscle, the blood supply of which was occluded by rubber bands.

33. Bell, J. R.; Clark, A. M., and Cuthbertson, D. P.: Experimental Traumatic Shock, J. Physiol. **92**:361, 1938.

experiment blood from the ischemic limb was allowed to flow into the general circulation for ten minutes before any was removed for transfusion into the control dog. In this experiment the control animal went into shock but improved after the transfusion was terminated, and it was alive the next morning. Although no conclusion can be deduced from 1 experiment, survival of this animal might be attributed to the fact that it did not receive the blood draining from the constricted limb immediately after release of the tourniquet. If a toxin is present at all in the limb to which a tourniquet is applied, it theoretically should be more concentrated in the first blood drained from the extremity just after release of the tourniquet.

It is obvious that if a toxin is present in the ischemic, or anoxic, limb it would be much more concentrated in the blood of the femoral vein draining from the limbs than in the systemic blood collected elsewhere. It was for this reason that blood from the shocked dog was collected from this source.

The limb subjected to the application of the tourniquet (nine to sixteen hours) was the seat of a variable amount of edema (even before release of the tourniquet), as has been observed by others, which presumably is caused by blood escaping into the limb through the femur (Blalock). After release of the tourniquet there was a surprisingly slight increase in the amount of edema, as determined by measurement; the exact amount would be difficult to measure in the individual limbs. Unquestionably, the level of application of the tourniquet would be directly related to the percentage of loss of fluid into the extremity. In general, the percentage of gain as compared with the total body weight would be increased if the level of application of the tourniquet was located farther toward the trunk, and vice versa. As stated previously, the total weight lost into the constricted limb in our experiments was only 2.1 per cent of the body weight, an amount definitely too small to explain death on the basis of loss of plasma or blood alone. The loss of plasma in our experiments is less than in the experiments of at least some other observers, probably because we applied the tourniquet at a slightly lower level. Since the studies on weight in the 10 experiments described in the table indicated loss of plasma as inadequate to explain death, comparative weights of the limbs of the 5 dogs used in the experiments on cross transfusion were determined on only one occasion. At this time the gain of weight in the ischemic limb, as determined by comparative weights after death, was only 0.7 per cent of the total body weight, or much less than the average in the animals not subjected to cross transfusion. A discrepancy in this direction might be expected in animals subjected to cross transfusion, since the efforts to aspirate the maximum amount of blood (by syringe) from the vein might tend to decrease the amount of plasma stagnating in the limb.

Theoretically, if blood flowing through the collateral veins (as well as the femoral veins) from the constricted limb were prevented from entering the general circulation, death could be postponed for days (until infection developed). In the 5 experiments described, no attempt was made to block the collateral veins. Removal of blood from the femoral vein might minimize development of any possible toxic action of the animal, and therefore life would be prolonged longer than in animals in which blood from all veins in the limb to which the tourniquet had been applied was allowed to enter the general circulation. The average duration of life following release of the tourniquet in animals in which blood from the femoral vein was diverted for transfusion into another dog was only five or ten minutes longer than that in animals in which no blood was removed after release of the tourniquet. It appears likely that heparin, which was administered to the 5 dogs subjected to cross transfusion (to prevent clotting), might tend to shorten life, since clotting in the veins in the 10 dogs not receiving heparin would delay escape of any toxic product present. Naturally a comparison of the duration of life in animals receiving and those not receiving heparin would throw light on the question.

No effort was made to determine the source of any toxic products which may have developed in the constricted limb. They presumably might be catabolic or bacterial in origin. The fact that half of the control animals receiving blood from the ischemic limb lived only two or three hours suggests that bacterial action was not probable, although it might be possible for bacteria to grow and produce toxins in the limbs to which the tourniquet had been applied for nine to sixteen hours.

SUMMARY

Tourniquet shock can be produced consistently in animals and is therefore particularly adaptable for study, but the extreme pain produced by the tourniquet makes it necessary to utilize some type of anesthesia. Prolonged anesthesia, whether produced by a barbital compound or a general anesthetic, is undesirable. Moreover, since nervous impulses are obviously so intensive, this factor might alter the data

derived from the experiment. To obviate these disadvantages we have adopted the procedure of cutting the spinal cord at the level of the lowest dorsal or the uppermost lumbar vertebra, two to four days before the experiment is to be performed. It is unwise to wait much longer, since the anesthesia induced in the lower extremities, which are dragged over the floor of the cage, may allow development of ulcers, infection, etc. Manipulation or operation may be conducted without pain on the lower extremities of the animal with no more anesthetic than a moderate dose of morphine. To keep the tourniquet anchored in one place a sterile nail can be driven deeply into the trochanter. In the experiments in which shock was produced by release of the tourniquet death always occurred if the tourniquet was left in place for at least nine hours. In 10 animals studied by this method, death occurred after an average of two hours and thirty-four minutes following release of the tourniquet. The average loss of plasma into the extremity before and following release of the tourniquet, as determined by the method of Blalock, was only 2.1 per cent of the total body weight, which is insufficient in itself to explain death.

To determine whether or not a toxin may have developed in the constricted limb and may have been an important factor in the pathogenesis of shock and death, we performed cross transfusion, injecting blood obtained from the distal portion of the femoral vein of the constricted limb into a normal (control) animal. To prevent increase in shock in the animal subjected to the application of the tourniquet through loss of blood, an equal amount of blood was removed from the recipient (control) dog and injected into the shocked animal.

Because of exigencies of war, work on the problem was interrupted; only 5 such experiments could be performed. Four of the 5 animals receiving blood from the constricted limb after release of the tourniquet died two to twelve hours after the transfusion was begun. The only dog to survive transfusion of blood which had circulated through the constricted limb was 1 which did not receive any blood from the constricted limb until ten minutes following release of the tourniquet. If a toxin were present in the constricted limb it would supposedly be more concentrated in the blood draining from the limb during the first few minutes following release of the tourniquet. If this were true, survival of this animal, which, however, did go into shock during the transfusion (but recovered afterward), might be explained.

MECKEL'S DIVERTICULUM

DYSPEPSIA MECKELI FROM HETEROTOPIC GASTRIC MUCOSA

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DEFINITION

The vitellointestinal duct is a communication between the midgut and the yolk sac of the embryo during the first few weeks of fetal life (fig. 1). Persistence of this duct or of portions of it gives rise to a deformity known as Meckel's diverticulum,[1] so called after J. F. Meckel, who was the first to publish an adequate description of the anomaly, in 1812,[2] though he had mentioned it in an earlier publication, in 1809.[3] According to Lichtenstein,[4] the diverticulum was mentioned by Hildanus in 1598. Lavater [5] mentioned it in 1671.[5] It was described by Littré in 1700 as being present in a hernia (Strohl and McArthur [6]). In the adult, Meckel's diverticulum usually rises from the antemesenteric portion of the ileum about 20 inches (50 cm.) proximal to the ileocecal valve, the distance being less directly as the age approaches infancy. However, it may be found at any point along the intestinal tract. In a like manner, it may vary greatly in length, from a fraction of an inch to as long as 2 feet (60 cm.). Some type of Meckel's anomaly is present in approximately 4 per cent of all newborn infants (Ladd [1]), though the rate of occurrence in adults is given as from 1 per cent to 3 per cent by different authorities (Curd,[7] Everhart [8] and Waugh and others [9]).

PATHOLOGY

Meckel's diverticulum may be present throughout the life of a person and yet cause no symptoms, but owing to the serious consequences of the pathologic conditions to which it is subject, it is always a source of great potential danger. It has been estimated that from 15 to 20 per cent of the diverticula are subject to pathologic changes which cause symptoms (Faust [10]). In other words, for every 2 diverticula found diseased there are 8 with no symptoms.

Before discussing the pathology of Meckel's diverticulum, it will be well to mention the various anatomic types that can occur. The anatomic descriptions which follow are drawn mainly from those of Callander [11] and Nygaard and Walters [12] (fig. 2 and 3). 1. The vitellointestinal duct may remain open, with the result that a fistula persists between the ileum and the skin of the umbilicus. 2. The vitellointestinal duct may be partially obliterated so that mucous membrane is present at the distal end at the umbilicus, whereas at its attachment to the ileum it has become a solid cord; it may be partially obliterated in its distal portion and opened at its attachment to the bowel, thus forming a diverticulum which is attached by a solid cord to the umbilicus; a diverticulum may be present with the obliterated cord attached to some point within the abdominal cavity; or a diverticulum from the bowel may be connected to persistent mucous membrane at the umbilicus by a cord of obliterated duct. 3. The duct may be completely obliterated with a cord remaining: (*a*) attached to the umbilicus, (*b*) hanging free in the abdominal cavity or (*c*) attached to some point within the

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2. Meckel, J. F.: Handbuch der pathologischen Anatomie, Leipzig, C. H. Reclam, 1812, vol. 1, pp. 533-557.

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5. Lavater, J. H.: De ἐντεροπεριστολή seu intestinorum compressione, Basilae, typ. J. Bertschi, 1672.

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7. Curd, H. H.: Histologic Study of Meckel's Diverticulum, Arch. Surg. **32**:506-523 (March) 1936.

8. Everhart, M. W.: Complications of Meckel's Diverticulum in Infancy and Childhood, J. Pediat. **17**: 483-489 (Oct.) 1940.

9. Waugh, J. M.; Herrell, W. D., and Crumpacker, L. K.: Peptic Ulcer in Meckel's Diverticulum Causing Intrinsic Intestinal Obstruction, Surgery **11**:385-391 (March) 1942.

10. Faust, L. S.: Meckel's Diverticulum with Unusual Clinical Manifestations, M. Clin. North America **15**:1483-1489 (May) 1932.

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12. Nygaard, K. K., and Walters, W.: Malignant Tumors of Meckel's Diverticulum, Arch. Surg. **35**:1159-1172 (Dec.) 1937.

abdominal cavity. 4. The duct may contain a cyst (*a*) in its central portion or (*b*) in its distal portion with a sinus opening in the umbilicus. 5. The duct may end in a blind pouch in the form of a pseudodiverticulum hanging free in the abdominal cavity, which is the usual anatomic condition found. 6. It may end in a simple blind pouch, and instead of hanging free in the abdominal cavity, it may be buried within the substance of the mesentery. 7. The diverticulum may have its own mesenteriolum. 8. There may be diverticulosis of Meckel's diverticulum.

The pathologic changes accompanying Meckel's diverticulum depend to a large extent on the anatomic deformities present. 1. If a fistula persists, intestinal contents drain to the abdomen from the umbilicus (Rentschler[13]). The discharge from such a fistula is extremely irritating and if the defect is not repaired the discharge may lead to digestion of the skin of the abdominal wall. There may be an omphalocele (Morrison and Neville[14]). 2. Intestinal obstruction results from rotation of the bowel on the long axis of the diverticulum or from coils of adjacent bowel becoming looped around the diverticulum when it is attached to the abdominal wall or to some point within the abdominal cavity. 3. The cystic

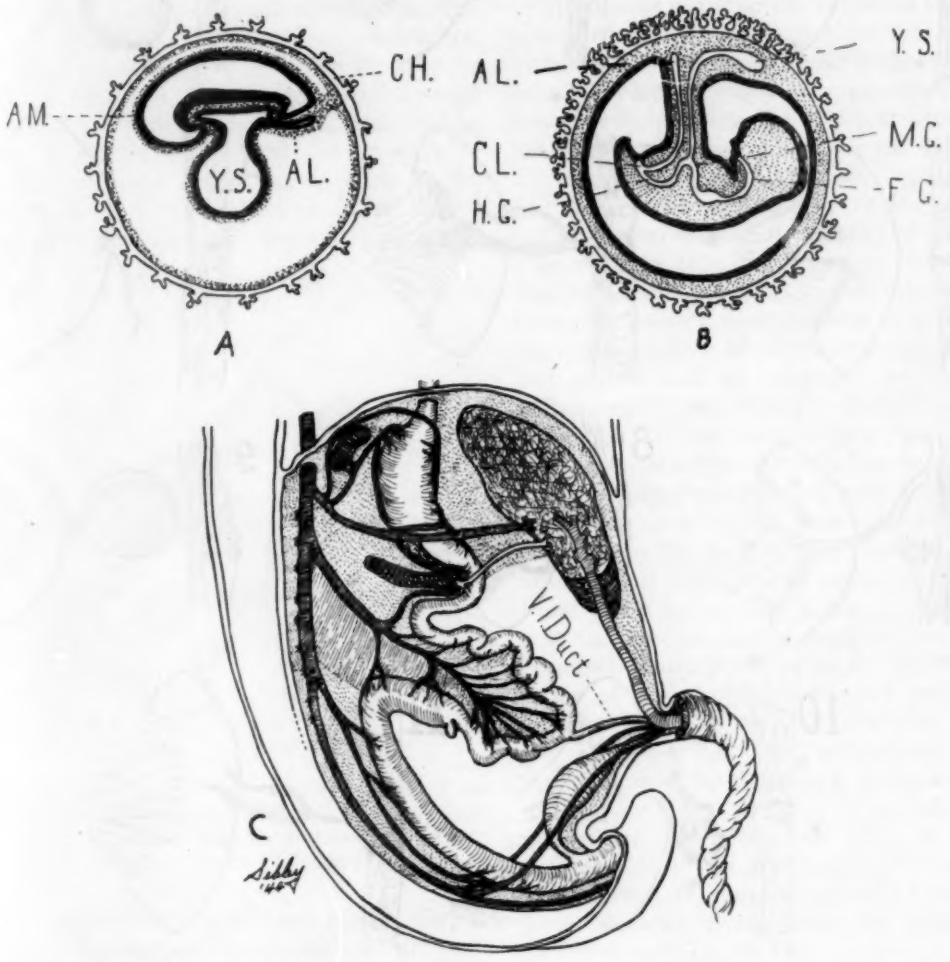

Fig. 1.—*A* and *B*, diagrams illustrating the formation of the vitellointestinal duct. In *A* there is a wide communication between the yolk sac and the midgut, so that it is virtually one large cavity. The allantois is present at this stage. In *B* the vitellointestinal duct has formed between the midgut and the yolk sac. *AL.* indicates allantois; *AM.*, amnion; *CH.*, chorion; *CL.*,cloaca; *F.G.*, foregut; *H.G.*, hindgut; *M.G.*, midgut; *Y.S.*, yolk sac. (Redrawn from Morris' Human Anatomy, edited by C. M. Jackson, ed. 9, Philadelphia, 1933, P. Blakiston's Son & Co.). *C*, diagram illustrating the relationship of the vitellointestinal duct to the intestinal tract and to the umbilicus. Meckel's diverticulum is formed by the persistence of this duct or parts of it. (Redrawn from Callander.[11])

13. Rentschler, C. B.: Persistence of Meckel's Diverticulum, Arch. Surg. **40**:694-695 (April) 1940.

14. Morrison, H. J., and Neville, R. L.: Omphalocele with Congenital Obstruction, Am. J. Dis. Child. **65**:781-784 (May) 1943.

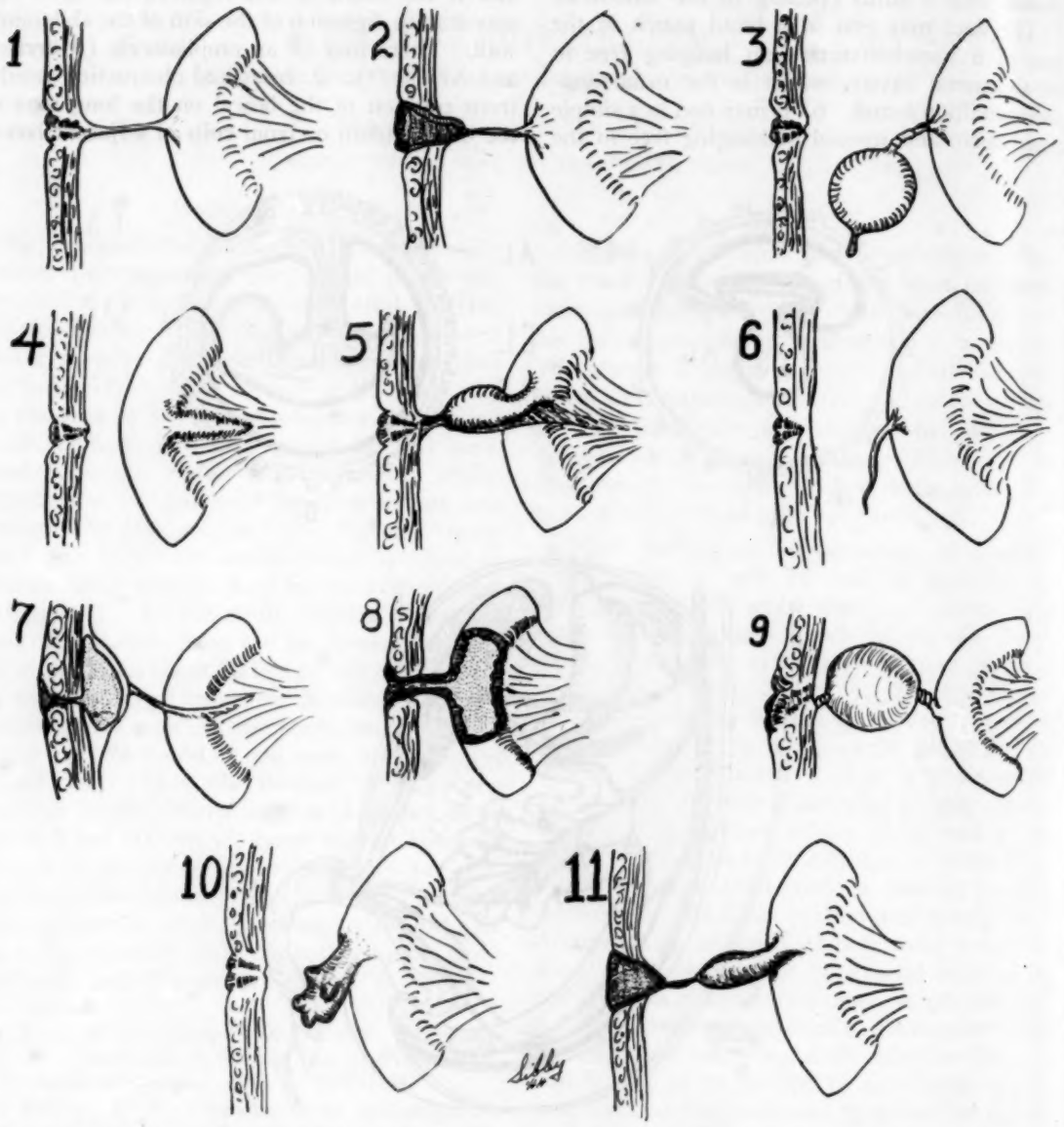

Fig. 2.—Diagrams illustrating some of the various anatomic types of Meckel's diverticulum: *1,* fibrous cord attached to the umbilicus from the ileum; *2,* persistent mucosa at the umbilicus attached to the ileum by a fibrous cord; *3,* cyst hanging from the ileum by a twisted fibrous cord; *4,* blind, tubular sac beneath the serosa of the mesentery of the ileum; *5,* blind, tubular diverticulum attached to the umbilicus by a fibrous cord, having its own mesenteriolum; *6* fibrous cord, remnant of the vitellointestinal duct, hanging free from the ileum (the cord may be attached to the adjacent bowel); *7,* cyst draining through the umbilicus, attached to the ileum by a fibrous cord; *8,* persistent, patent vitellointestinal duct, lined with mucosa, draining to the umbilicus from the ileum; *9,* cyst attached distally to the umbilicus and proximally to the ileum by a twisted fibrous cord; *10* saccular diverticulum of the ileum showing diverticulosis of the diverticulum; *11,* saccular diverticulum of the ileum attached by a fibrous cord (obliterated vitellointestinal duct) to a saccular area of mucosa in the umbilicus (similar to the diverticulum in the case reported by Ehrenpreis [15]). (Diagrams 7, 8 and 9 were redrawn from Callander [11]; diagrams 1 to 6 inclusive, from Nygaard and Walters.[12])

type is thought to result from a rotation of the bowel in early fetal life causing a spiral twist in the long axis of the vitellointestinal duct (Callander [11]). Sometimes the cyst is situated just beneath the umbilicus and drains to the abdomen through the umbilicus (Ehrenpreis [15]). 4. The vitellointestinal duct is usually obliterated and absorbed during the seventh week of intrauterine development (Matt and Timpone [16]). However, it may fail to become absorbed so that a fibrous cord persists. Intestinal obstruction results from rotation of the bowel on the cord or from loops of bowel becoming twisted around the cord in a manner similar to that described in item 2. 5. Inflammation occurs in the walls of Meckel's diverticulum, just as it does in the appendix. Such inflammation is called diverticulitis. The diverticulitis may be acute and

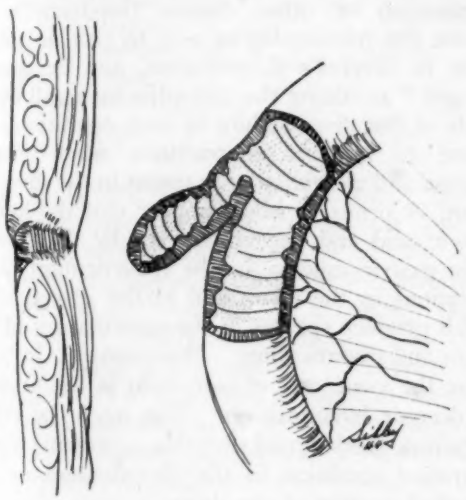

Fig. 3.—Diagram illustrating a cross section of the most common type of Meckel's diverticulum, a simple tubular, blind sac arising from the antemesenteric aspect of the ileum. (Redrawn from Callander.[11])

severe, or it may be chronic and mild. The inflammatory process may extend beyond the walls of the diverticulum and give rise to peritonitis. Coley [17] has reported a case of tuberculosis in Meckel's diverticulum. 6. Heterotopic tissues may be present in Meckel's diverticulum in the form of pancreatic, biliary, duodenal, ileal, colonic and gastric tissues (Wilson,[18] Salzer,[19] Zencker,[20] Hunt,[21] Curd [7] and Greenblatt, Pund and Chaney [22]). Heterotopic tissues occur in approximately 25 per cent of the cases of Meckel's diverticulum (Matt and Timpone [16]). These tissues are thought to be present as a result of one or more conditions. Some of the theories listed by Greenblatt, Pund and Chaney [22] are: (*a*) Albrecht's theory that the entoderm of the primitive gut is composed of pluripotential cells and that some of these cells persist in the diverticulum and give rise to the various types of tissues found; (*b*) Farr and Penke's theory that the cells represent vestiges of a primitive digestive system which during the first few weeks of fetal life secretes digestive juices for the utilization of the contents of the yolk sac during this period; (*c*) the dysembryoma theory of Pierre Masson, and (*d*) the reimplantation theory of Shaetz. The most common type of heterotopic tissue found in Meckel's diverticulum is gastric mucosa. It has been conclusively demonstrated that this gastric mucosa is capable of secreting hydrochloric acid and pepsin just as does that in the stomach (Dragstedt [23] and Waugh, Herrell and Crumpacker [9]). It has been shown that the gastric mucosa in Meckel's diverticulum is acted on by the secretory hormone that stimulates secretion by the mucosa of the stomach, and that the secretion in the diverticulum occurs at the same time that it does in the stomach (Greenblatt, Pund and Chaney [22]). It has also been shown that the mucosa of the intestine becomes progressively more sensitive to the irritating properties of hydrochloric acid and pepsin as the distance from the stomach increases (Matthews and Dragstedt [24]). The hydrochloric acid and pepsin secreted by the gastric mucosa in Meckel's diverticulum are probably responsible for the ulcerations that sometimes occur in the diverticulum. Womack and Siegert [25] state that the first account of hydrochloric acid being secreted from Meckel's diverticulum was made by Till-

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22. Greenblatt, R. B.; Pund, E. R., and Chaney, R. H.: Meckel's Diverticulum, Am. J. Surg. **31**:285-293 (Feb.) 1936.

23. Dragstedt, L. R.: Ulcus Acidum of Meckel's Diverticulum, J. A. M. A. **101**:20-22 (July 1) 1933.

24. Matthews, W. D., and Dragstedt, L. R.: Etiology of Gastric and Duodenal Ulcer: Experimental Studies, Surg., Gynec. & Obst. **55**:265-286 (Sept.) 1932.

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mans in 1882. When an ulcer has formed, there may be an associated hemorrhage from the walls of the ulcer (Waugh, Herrell and Crumpacker,[9] Everhart,[8] Weiner and Seley,[26] Higgons and Gundy [27] and Christopher and Blessing [28]). However, hemorrhage also occurs from the walls of the ileum owing to the irritating effects of the acid secreted by the heterotopic tissue within the diverticulum (Higgons and Gundy,[27] Mason and Graham,[29] Cobb [30]). The peptic ulcer formed by the action of the acid from the heterotopic tissue may perforate and cause peritonitis. 7. Tumors occur in Meckel's diverticulum, and they may be benign or malignant (Greenblatt, Pund and Chaney,[22] Koucky and Beck,[31] Gray and Kernohan,[32] Weir,[33] Nygaard and Walters [12]). 8. Intussusception occurs from invagination of the diverticulum per se or from invagination due to the presence of a tumor (Harkins,[34] Bowen,[35] Gray and Kernohan [32]). The diverticulum may become the accidental reservoir of foreign bodies. Numerous reports of this have been made, revealing a great variety of foreign bodies, such as fish bones, pins, needles, grains of corn, cherry seeds and gallstones, and other types of concretions (Womack and Siegert,[25] Mulsow [36] and Giles and MacCarty [37]). Foreign bodies may perforate the walls of the diverticulum and set up infection within the walls of the diverticulum and frequently produce peritonitis. They may produce pressure erosion of the wall of the diverticulum and they may cause intestinal obstruction.

26. Weiner, S. B., and Seley, G. P.: Bleeding Meckel's Diverticulum in Ten Months' Old Infant, J. Mt. Sinai Hosp. **5**:620-626 (Jan.-Feb.) 1939.

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36. Mulsow, F. S.: Meckel's Diverticulum Containing Calculi, Am. J. Digest. Dis. **10**:188-189 (May) 1943.

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DYSPEPSIA MECKELI

Although any of the pathologic conditions that have been listed may occur, the ones most commonly found may be grouped into three categories, namely: (1) inflammatory type; (2) peptic ulcer type with or without hemorrhage, and (3) intestinal obstruction type with or without intussusception. It would appear that another phase of the peptic ulcer type is being seen and not being recognized. It is the group of diverticula that contain heterotopic gastric mucosa which when examined show no evidence of inflammation or other disease. Goodman [38] has shown the relationship of acid to pain in peptic ulcer of Meckel's diverticulum, and he quoted Burger [39] as stating that the adjacent small bowel walls of the diverticulum in such conditions are prone to spasmic contractions when gastric mucosa and ulceration are present in the diverticulum. A priori, it would appear that the hydrochloric acid and pepsin secreted by the heterotopic gastric mucosa in the diverticulum cause irritations in the ileum and in the diverticulum which produce spasms in the musculature of the ileum and diverticulum. These spasms, in turn, cause the symptoms of pain even in the absence of ulcer or inflammation. This might be called dyspepsia Meckeli and probably represents a preulcerative condition in the diverticulum or the marginal portion of the ileum.

CLASSIFICATION

Attempts have been made to classify the diseases of Meckel's diverticulum. The best classification is probably that of Greenblatt and his coworkers.[22] Briefly, this classification is as follows:

1. Peptic ulcer type
   - (*a*) Gastric mucosa without ulceration
   - (*b*) Gastric mucosa with ulceration
   - (*c*) Ulceration with hemorrhage
   - (*d*) Ulceration without hemorrhage
2. Obstructive type
   - (*a*) Intussusception
   - (*b*) Volvulus
   - (*c*) Congenital bands and adhesions
   - (*d*) Contents of hernia

38. Goodman, B. A.: Meckel's Diverticulum, Arch. Surg. **36**:144-162 (Jan.) 1938.

39. Burger, W.: Ueber das Meckel'sche Divertikel mit Magenschleimhaut, Inaug. Dissert., Heidelberg, J. Horning, 1932.

3. Diverticular type
   (*a*) Simple acute inflammation
   (*b*) Perforated and gangrenous
   (*c*) Chronic inflammation
4. Umbilical type
   (*a*) Fecal fistula
   (*b*) Umbilical adenoma
   (*c*) Prolapsed intestine through fistula
5. Tumor type
   (*a*) Benign
      (1) Carcinoid
      (2) Enterocystoma
      (3) Adenoma
      (4) Mesodermal tumor
   (*b*) Malignant
      (1) Carcinoma
      (2) Sarcoma
   (*c*) Heterotopic
      (1) Pancreatic
      (2) Gastric
      (3) Biliary
      (4) Colonic
      (5) Jejunal
      (6) Duodenal, etc.
6. Incidental type
   Normal tissue of ileum

SYMPTOMS

The signs and symptoms that occur from Meckel's diverticulum depend to a great degree on the anatomic disposition of the tissues and the pathologic changes involved in the diverticulum. Since these factors are extremely variable, it can be readily seen that the signs and symptoms also may be diversified. The presence of a fecal fistula or prolapsed intestine at the site of the umbilicus can be determined by inspection of the abdomen. A cyst within the abdominal cavity may be detected by palpation of the abdomen, though it may be misinterpreted as being of pancreatic origin. The cyst may cause abdominal pains of a vague description, usually localized around the umbilicus. If the cyst is draining from the umbilicus, it can be probed or iodized oil may be injected for roentgenologic diagnosis. The other signs and symptoms of disease in Meckel's diverticulum fall into three groups, namely: (1) the obstructive type, (2) the inflammatory type and (3) the peptic ulcer type. The signs and symptoms of intestinal obstruction may be mild with progression to advanced severity, or they may be severe from the beginning. If the obstruction is caused by intussusception, the signs and symptoms are the same as intussusception from any other cause. If the obstruction is due to incarceration of the diverticulum in a hernia, the signs and symptoms are those of incarcerated hernia. Intestinal obstruction from a tumor in the diverticulum is determined by operation for intestinal obstruction. The occurrence of diverticulitis may give rise to signs and symptoms which so closely resemble those of appendicitis that it is almost impossible to distinguish the one from the other. The pain and tenderness of diverticulitis are frequently greatest in the neighborhood of the umbilicus, or just below it and to the right. Sometimes the pain is referred to the epigastrium. The signs and symptoms of the peptic ulcer type may fall into three categories: (1) pain, (2) melena and (3) age. The pain of the peptic type is likely to resemble that of duodenal ulcer, having a definite time relation to the ingestion of food. The pain is usually localized in the neighborhood of the umbilicus or in the epigastrium. The melena is usually periodic. It may be insidious or severe. The hemorrhages are usually of considerable volume, but the period of bleeding is of short duration, being characterized by the presence of fresh blood mixed with some old blood, especially in the form of small clots. Most of the patients reported to have bleeding as a symptom have been under 15 years of age. The diagnosis of hemorrhage caused by Meckel's diverticulum is usually made by exclusion, since roentgenologic, proctoscopic and laboratory studies nearly always give negative results.

In 5 of the cases reported in this paper, heterotopic gastric mucosa was found in the diverticulum. In none of the 5 cases was there any evidence of inflammation in the appendix or in the diverticulum. There was a history of rather severe abdominal pain, the white blood cell counts were slightly elevated and all the patients seemed to have appendicitis. Three of them had pain and tenderness in the area of the umbilicus and slightly below it. It is believed that these 5 cases were instances of a type of dyspepsia or of a preulcerative phase of the peptic ulcer type of syndrome.

TREATMENT

The treatment of Meckel's diverticulum is surgical. It must be directed toward relieving the symptoms produced by the diverticulum. If obstruction is present, it must be relieved. If intussusception is present, it must be reduced surgically. If a fistula is present, it must be closed. If the diverticulum is enclosed in a hernia sac, it must be reduced. If recurrent pains are the symptoms, they must be relieved. Furthermore, all procedures carried out for the relief of symptoms caused by Meckel's diverticulum must include excision of the diverticulum. Matt and Timpone [16] and Wilson [18] stated the belief that the gastric mucosa frequently found in Meckel's diverticulum may extend to the walls of the ileum at the base of the diverticulum; they recommended wide excision or segmental resection of the ileum containing the diverticulum with

reestablishment of continuity of the bowel. However, according to the observations of Curd [7] in a histologic study of Meckel's diverticulum, this wide excision would not appear to be necessary. Curd stated that the heterotopic gastric mucosa is always found in the distal part of the diverticulum. When the diverticulum is excised, closure should be made accurately in a transverse plane which is perpendicular to the long axis of the bowel. Morrison and Neville [14] reported a case of omphalocele in an infant 60 minutes old which they successfully closed. Rentschler [13] reported a case of successful closure of a fistula in a 3 month old infant. In the management of intussusception great care must be taken to exclude Meckel's diverticulum, since the presence of this condition may be masked by the intussusception. If a diverticulum is found in a hernia sac it should be replaced within the abdomen, the hernia repaired and the diverticulum excised immediately through a separate incision (Harrington [40]).

PROGNOSIS

The over-all mortality rates reported have been alarmingly high. Some of the mortality rates range from 9.3 per cent (Goodman [38]) to as high as 57 per cent (Everhart [8]). It is probable that the mortality rate can be greatly reduced by early diagnosis and by early surgical operation in those cases in which Meckel's diverticulum may possibly be present.

REPORT OF CASES [41]

CASE 1.—A white woman aged 20 was admitted to the hospital on June 30, 1938 with a chief complaint of pain in the right lower quadrant of the abdomen. Her history revealed that two years prior to admission she began having periodic attacks of pain in the right lower quadrant of the abdomen, several of which were rather severe and lasted for one or more days. During the two weeks preceding admission she had almost daily attacks of pain in the right lower quadrant of the abdomen. It was noted on the chart that the patient was of a nervous temperament and worried a great deal over minor problems. The physical examination gave essentially negative results except for tenderness of moderate degree in the right lower quadrant of the abdomen, slightly medial to McBurney's point. The red blood cell count was 4,900,000; the value for hemoglobin, 90 per cent (Sahli), and the white blood cell count, 9,500, with polymorphonuclear cells 88 per cent and lymphocytes 12 per cent. Examination of the urine showed it to be normal. The temperature was 98 F., the pulse rate 82 and the respiratory rate 18. She was observed overnight in the hospital, and the following morning the findings were essentially the same. It was decided that operation was indicated. A preoperative diagnosis of appendicitis was made. A right rectus incision was employed. The appendix was found to be normal and exploration of the ileum revealed Meckel's diverticulum, 4 cm. in length, on the antemesenteric border, approximately 20 inches (50 cm.) from the ileocecal valve. The diverticulum was removed in a transverse plane, and the stump was closed with two rows of continuous sutures of surgical gut. The wound healed by first intention, and she was dismissed from the hospital on July 7. She was seen two years later and found to be completely relieved of the periodic abdominal distress. Microscopic examination of the tissue removed revealed a diverticulum containing gastric mucosa.

CASE 2.—A girl 8 years old was admitted to the hospital Aug. 31, 1939 with a chief complaint of pain in the right lower quadrant of the abdomen of two days' duration. Her history revealed that she had had no previous attacks similar to the present illness. This attack began with vague generalized pain in the right side of the abdomen associated with nausea and vomiting, which localized to finger point pain in McBurney's area at the time of admission. Physical examination revealed marked tenderness over McBurney's point, voluntary reflex rigidity of the abdominal muscles and audible borborygmus. The temperature was 100.4 F., the pulse rate 108 and the respiratory rate 24. The red blood cell count was 4,640,000; the value for hemoglobin, 80 per cent (Sahli), and the white blood cell count, 11,650, with polymorphonuclear cells 84 per cent and lymphocytes 16 per cent. Urinalysis revealed the presence of acetone. The preoperative diagnosis was acute appendicitis, with probable Meckel's diverticulum. A right rectus incision was employed. The appendix was found to be practically normal. There was a rather marked lymphadenitis in the mesentery of the ileum. Exploration of the ileum revealed a large diverticulum, about 5 cm. in length, on the antemesenteric portion of the ileum, approximately 14 inches (35 cm.) from the ileocecal valve. The appendix and the diverticulum were excised. The stump of the diverticulum was sutured with three rows of fine catgut suture in a transverse plane. The patient was dismissed from the hospital on September 7. Follow-up revealed no recurrence of the abdominal symptoms five years after the operation. The microscopic examination of tissue removed revealed the diverticulum to contain ileal mucosa with no heterotopic tissue present.

CASE 3.—A 9 year old boy was admitted to the hospital on May 7, 1941 with a chief complaint of abdominal pains associated with melena of three days' duration. The illness began May 4, with epigastric pain which migrated to the umbilicus. The patient became weak and pale and appeared to be in a state of mild shock. He passed a number of bloody stools in which there were fresh blood and dark blood clots. He was seen by Dr. Berkeley Neal, who obtained a history of a similar attack two years before associated with intestinal hemorrhage, and another a year later. Roentgenologic studies after the first attack revealed no cause for the bleeding. Physical examination revealed an extreme pallor of the skin. There was slight

40. Harrington, S. W.: Strangulated Meckel's Diverticulum in Right Femoral Hernia, S. Clin. North America **6**:1180-1190 (Oct.) 1926.

41. Material in cases 1, 2 and 3 was obtained at the Lewis-Gale Clinic, Roanoke, Va., prior to my entrance into active military service. The material in cases 4 to 10 was obtained in the surgical service of a station hospital. Cases 11 and 12 were observed after this paper was originally written.

abdominal tenderness in the area of the umbilicus. The child appeared quite weak from hemorrhage. Proctoscopic examination revealed nothing abnormal. The red blood cell count was 2,690,000; the value for hemoglobin, 55 per cent (Sahli), and the white blood cell count, 3,300, with polymorphonuclear cells 56 per cent and lymphocytes 44 per cent. Urinalysis revealed the pressure of acetone. The temperature was 99.2 F., the pulse rate 98 and the respiratory rate 20. A series of gastrointestinal roentgen studies was made on May 8, 9 and 10 with Meckel's diverticulum in mind. This series was negative. It was decided that the patient probably had Meckel's diverticulum despite the negative roentgenologic findings. A transfusion of 500 cc. of whole blood was administered on May 8. Laparotomy was performed May 12, with a right rectus incision. On entering the abdominal cavity it was found that there was an incomplete rotation of the colon. The cecum was located in the right upper quadrant of the abdomen at the point where the hepatic flexure normally should be. The ileum was retroperitoneal in the distal 12 inches (30 cm.). A diverticulum 6 inches (15 cm.) long arising from the antemesenteric border of the ileum, 14 inches (35 cm.) above the ileocecal valve, was found. It was attached to the abdominal wall at the umbilicus. Several coils of small bowel were looped around the diverticulum producing a partial strangulation of the diverticulum. The diverticulum was released from its attachment to the abdominal wall and removed from the ileum over a Payr clamp. The stump was inverted in a transverse plane with two rows of catgut suture. The appendix was removed. The following day it was apparent that the patient was not doing well and appeared to be in a state of mild shock. He was given parenteral fluids and general supportive measures and seemed to improve. On May 15 he had a large intestinal hemorrhage which continued in spite of transfusions and other supportive measures. It was decided to reopen the abdomen. On May 15 the old incision was reincised and it was found that the inverted stump of the resected diverticulum was bleeding, as well as the mucosa in the adjacent wall of the ileum. It was necessary to resect this portion of the ileum. The distal stump of the ileum was closed near the cecum, and the proximal part of the ileum was anastomosed to the ascending colon. Following this the patient made an uneventful recovery and was dismissed from the hospital on May 29 completely recovered. Communication was received on Jan. 12, 1944, stating that he had no recurrence of the gastrointestinal pain or bleeding. Examination of tissue removed revealed marked inflammation in the wall of the diverticulum and the adjacent ileum. No heterotopic gastric mucosa could be found after careful search by the pathologist.

CASE 4.—A man aged 22 was admitted to the hospital Nov. 19, 1942 with a chief complaint of severe pain in the right lower quadrant of the abdomen of about fourteen hours' duration. He had become ill early the same morning, with generalized abdominal pain followed immediately by nausea and vomiting. During the day the pain migrated to the right lower quadrant of the abdomen and remained severe. His past history revealed nothing of significance. Physical examination revealed slight abdominal distention with acute point tenderness at McBurney's point in the right lower quadrant of the abdomen and rather marked reflex spasm of the musculature of the right side of the abdomen. The temperature was 98.6 F., the pulse rate 96 and the respiratory rate 22. The red blood cell count was 5,050,000; the value of hemoglobin, 80 per cent (Tallqvist), and the white blood cell count, 11,550, with polymorphonuclear cells 78 per cent and lymphocytes 21 per cent. Urinalysis gave normal results. A diagnosis of acute appendicitis was made, because the symptoms seemed to be far more severe than the blood count, temperature and pulse rate would indicate. Operation was performed through a Battle incision, and the appendix was found to be normal. When the ileum was explored, a large diverticulum was found arising from the antemesenteric portion approximately 2 feet (60 cm.) from the cecum. This diverticulum was about 8 cm. in length and contained three saccular projections in the form of pseudodiverticuli, arising from its wall. The diverticulum was removed in a transverse plane, and the stump was closed with 3 rows of fine surgical gut suture. The appendix was removed. The patient made an uneventful recovery and was dismissed from the hospital on December 5. He was last seen in July 1943 and had had no recurrence of his symptoms. Microscopic examination of tissue removed revealed Meckel's diverticulum, with heterotopic duodenal and gastric mucosa.

CASE 5.—A man aged 20 was admitted to the hospital on Oct. 29, 1943 with a chief complaint of pain in the area of the umbilicus and the lower part of the abdomen of two days' duration. He gave a history of having become ill two days prior to admission with vague pains in the area of the umbilicus and the lower midline area of the abdomen. This was followed by a type of indigestion characterized by acid eructations which contained bile. The diagnosis of cholecystitis was made, and he was treated conservatively for two days. When his condition seemed to become worse, he was transferred to this hospital. On arrival here, he was still complaining of vague pains in the lower part of the abdomen, with continued episodes of acid and gaseous eructations and an increasing sensation of abdominal distention. The medical officer who first saw him noted on the chart that he did not look very sick. Physical examination revealed slight to moderate abdominal tenderness just below the umbilicus. There was moderate tympanites. There was no abdominal rigidity. The temperature was 98 F., the pulse rate 76 and the respiratory rate 18. The red blood cell count was 5,150,000 and the white blood cell count 14,050, with polymorphonuclear cells 86 per cent, lymphocytes 13 per cent and eosinophils 1 per cent. The value for hemoglobin was 85 per cent (Tallqvist). He was put to bed and treated conservatively by the medical service. Late in the afternoon of October 30 he was seen in consultation by members of the surgical service. It was ascertained at this time that the patient had had a previous attack similar to the present illness twenty months before, at which time he was treated by siphonage with a Miller-Abbott tube. He made a complete recovery and was free of symptoms except for occasional spells of what he described as indigestion, which seemed to follow certain meals. Physical examination at this time revealed about the same conditions as on the previous day. The white cell count was 5,200, with polymorphonuclear cells 74 per cent and lymphocytes 26 per cent. It was decided to try a Miller-Abbott tube again. The tube was passed; fluids were administered parenterally, and the patient seemed to be improved the following morning. Later in the day (October 31) he pulled the Miller-Abbott tube out and it was necessary to reinsert it. A scout roent-

genogram of the abdomen taken on October 30 revealed what appeared to be an intestinal obstruction in the ileum. It was thought that the obstruction was not complete, since gas and fecal matter were getting through. Conservative treatment was continued on October 31. A blood count on October 31 revealed a white cell concentration of 5,350. The temperature was 98 F., the pulse rate 78 and the respiratory rate 18. On November 1 there was a definite change. His temperature rose suddenly to 101 F., his pulse rate to 128 and his respiratory rate to 28. The pain in the lower part of the abdomen became acutely severe; rigidity developed in the musculature of the abdominal wall, and the white blood cell concentration rose to 17,900, with polymorphonuclear cells 98 per cent and lymphocytes 2 per cent. The abdomen was opened, since it was feared that something had perforated.[42] When the abdominal cavity was entered, a large quantity of purulent fluid was encountered. There was a generalized plastic peritonitis which seemed to originate in the neighborhood of the appendix. Drains were placed in the pelvis and near the cecum and one toward the midline. After this procedure the patient seemed to improve slightly but continued to have a temperature varying between 101 and 102 F., with the pulse rate ranging from 100 to 128. He died on November 10, ten days after the operation. During the postoperative period continuous duodenal siphonage was maintained and feeding was parenteral. Autopsy revealed gangrenous Meckel's diverticulum and generalized peritonitis; associated with this condition was septicemia with acute vegetative endocarditis. Microscopic examination of the diverticulum revealed a gangrenous diverticulitis. Heterotopic gastric mucosa was present.

Case 6.—A youth aged 18 was admitted to the hospital Dec. 10, 1943 with a chief complaint of abdominal pains of twenty-four hours' duration. The history revealed that he became ill in the afternoon of December 9 with slight abdominal pains centered mainly around the umbilicus which were soon followed by periods of nausea and anorexia. The pains gradually became more severe, so that when he reached the hospital, twelve hours later, he complained of agonizing pains in the lower part of the abdomen. The past history revealed that he had an attack similar to the present illness about one year before, at which time he was sick in bed for a week and was treated conservatively. At that time he was told he probably had appendicitis. Physical examination on his admission to this hospital revealed moderate tenderness in the midline just below the umbilicus. There was no rigidity and no rebound pain, but he complained of severe subjective pains in the lower part of the abdomen. The temperature was 99.4 F., the pulse rate 88 and the respiratory rate 24. The red blood cell count was 4,890,000, and the white blood cell concentration, 11,900, with polymorphonuclear cells 60 per cent and lymphocytes 40 per cent; the value for hemoglobin was 85 per cent (Tallqvist). Owing to the vague nature of the symptoms, it was decided to delay the operation. The following morning the subjective pain was still severe but there was only moderate tenderness, which was in the midline just below the umbilicus. Because of the persistence of the symptoms it was decided that operation was indicated, with the probable diagnosis of appendicitis. The Battle incision was employed.[43] The appendix was normal. On exploration of the ileum, Meckel's diverticulum was found about 18 inches (45 cm.) from the ileocecal valve, measuring 3 cm. in length on the antemesenteric border. It was excised in a transverse plane, and the stump was closed with three rows of fine surgical gut sutures. The appendix was also removed. Recovery was rapid and uneventful. The patient was discharged from the hospital Jan. 20, 1944. Examination of tissue revealed the presence of typical heterotopic gastric mucosa in the diverticulum.

Case 7.—A man aged 22 was admitted to the hospital Jan. 2, 1944 complaining of rather severe pain in the lower midline region of the abdomen of three days' duration. The cadet stated that on Dec. 30, 1943 he was struck in the abdomen while boxing but that he had no symptoms until six hours after the injury, when he began to have vague pains in the lower part of the abdomen. The pain was intermittent for two days and then began to be almost constant. The morning of admission he became nauseated and vomited and the pains in the abdomen became more severe. The past history was entirely irrelevant. Physical examination revealed the abdomen to be moderately tender in the lower midline region, with moderate rigidity and rebound pain referred to the umbilicus. The temperature was 98.4 F., the pulse rate 80 and the respiratory rate 20. The white blood cell count was 10,500, with polymorphonuclear cells 68 per cent and lymphocytes 32 per cent. Urinalysis gave negative results. After a brief period of observation, it was decided that the patient had an abdominal condition requiring surgical intervention and probably had Meckel's diverticulum. Exploration was carried out through a Battle incision. The appendix was normal, and there was no evidence of injury within the abdominal cavity, but Meckel's diverticulum, 4 cm. in length, was present about 18 to 20 inches (45 to 50 cm.) above the ileocecal valve on the antemesenteric portion of the ileum. The diverticulum was excised in a transverse plane and the stump was closed with two rows of continuous fine surgical gut sutures. The appendix was also removed. The man made an uneventful recovery and was discharged from the hospital January 23. Microscopic examination of the tissues removed revealed the presence of typical heterotopic gastric mucosa within the diverticulum.

Case 8.—A girl 10 years old was admitted to the hospital Feb. 2, 1944 with the chief complaint of abdominal pain, anorexia and nausea of three days' duration. The history revealed that the patient had been subject to recurrent episodes of abdominal pain with anorexia and slight nausea lasting from two to several days over a period of about one year. She was described as having a finicky appetite, and a great deal had been done in the way of adjusting diets in order to prevent the occurrence of the gastrointestinal symptoms. The present attack began eight days prior to her admission with vague pains in the area of the umbilicus, slight nausea and the complaint of abdominal distress after eating. Physical examination revealed a somewhat thin, small girl with slight tenderness just to the right of the umbilicus and rebound pain referred to the umbilicus. The temperature was 98.6 F., the pulse rate 88 and the respiratory rate 20. The red

42. Operation was performed by Captain H. W. Gourlie.

43. Operation was performed by Captain G. S. Edgerton.

blood cell count was 4,850,000, and the white blood cell count, 4,900, with polymorphonuclear cells 36 per cent, lymphocytes 60 per cent and eosinophils 4 per cent. The value for hemoglobin was 80 per cent (Tallqvist). Examination of the stools and of the urine revealed nothing significant. In view of the fact that the patient had been in the hospital on previous occasions for a similar condition and in view of the physical findings, it was decided that operation was indicated. The preoperative diagnosis was probable appendicitis. A Battle incision was employed. The appendix was found to be normal but was removed. Meckel's diverticulum, 5 cm. in length, was found 15 inches (40 cm.) from the cecum on the lateral aspect of the ileum. Its blood supply was derived from its own mesenteriolum. The diverticulum was excised in a transverse plane, and the stump was closed with three rows of fine surgical gut sutures. The patient made an uneventful recovery and was discharged from the hospital February 12. Follow-up at the time of writing reveals the patient to be gaining in weight and to be relieved completely of her gastrointestinal disturbances. Microscopic examination of the diverticulum revealed the presence of heterotopic gastric mucosa.

CASE 9.—A man aged 46 fell dead after engaging in physical exercise in the line of duty on March 8, 1944. As far as could be determined, his past history was essentially irrelevant. No history could be obtained of any gastrointestinal disturbance. Autopsy revealed the cause of death to be a coronary occlusion. Meckel's diverticulum, 6 inches (15 cm.) long, was found on the small intestine 46 inches (115 cm.) from the cecum. Microscopic examination of the diverticulum revealed the presence of heterotopic gastric mucosa.

CASE 10.—A man aged 25 died March 6, 1944 as a result of injuries received in an airplane crash. As far as could be determined, he had no history of gastrointestinal disease prior to the accident. Autopsy revealed the cause of death to be due to exsanguination from lacerations of large blood vessels in the chest. Meckel's diverticulum, about 8 inches (20 cm.) long, was found on the ileum about 20 inches (50 cm.) from the cecum. Microscopic examination of the diverticulum revealed normal ileal tissue and no heterotopic tissue.

CASE 11.—E. E. S., a white man, aged 55, was admitted to the hospital on July 27, 1944 with the diagnosis of lumbago. He became ill at 8 a. m., while bending over in his routine work. At 4 p. m. of the same day he was complaining of midepigastric pain of increasing severity. The white blood cell count was 11,050, with polymorphonuclear cells 80 per cent and lymphocytes 20 per cent; the red blood cell count was 4,200,000; the value for hemoglobin was 80 per cent (Tallqvist). He was observed until 10 p. m., when the pains in the epigastrium became extremely severe. At this time his abdomen was boardlike in rigidity. His past history revealed that he had had a similar attack six years prior to admission to the hospital, at which time he was in bed for three weeks. There was also a history of frequent episodes of dyspepsia, characterized by gaseous eructations and epigastric distress, over a period of twenty years. About a year before he had been treated for an unconfirmed duodenal ulcer.

With the development of boardlike rigidity in the abdomen and the severe pain, it was decided that exploration was indicated. The possibility of Meckel's diverticulum was entertained before operation. At operation the appendix was found to be normal. There was no other disease in the abdominal cavity except a diverticulum about 2 inches (5 cm.) long. It was 24 inches (6 cm.) from the cecum on the antemesenteric border of the ileum. The appendix and the diverticulum were removed, and the patient made an uneventful recovery. Microscopic examination of the diverticulum revealed the presence of gastric mucosa without inflammation.

CASE 12.—L. K. was admitted to the hospital on Aug. 11, 1944 with the diagnosis of acute appendicitis. She became ill at 9 a. m. of the same day, with pains in the midepigastrium, associated with nausea and vomiting. She took a laxative and administered an enema to herself. These measures failed to give relief. She was examined at 4 p. m. and found to have moderate tenderness in the right lower quadrant of the abdomen with persistent pain in the midepigastrium. The white blood cell count was 9,000 at 4 p. m. She was advised at this time to remain in bed and rest. She improved slightly, but at 8 p. m. the epigastric pain and nausea returned. She was admitted to the hospital, with a white blood cell count of 12,400. Urinalysis gave normal results. There was distinct tenderness in McBurney's area, but all of the pain of which she complained was in the midepigastrium. The history revealed repeated attacks of mild epigastric distress at intervals during the past two years. The diagnosis was appendicitis, and operation was performed at 11 p. m. The appendix was normal. There was a small follicular cyst on the right ovary, and Meckel's diverticulum, rather large, was situated 12 inches (30 cm.) from the cecum, on the antemesenteric border of the ileum. It was 6 cm. long and contained three small pseudodiverticula. The appendix and the diverticulum were removed, and the cyst on the ovary was punctured. The patient made an uneventful recovery. Microscopic examination of the diverticulum revealed the presence of gastric mucosa without inflammation.

COMMENT

The object in presenting these cases is primarily to call attention to the fact that there are cases in which Meckel's diverticulum containing heterotopic gastric mucosa may cause symptoms somewhat akin to those of diverticulitis but in which there is no evidence of inflammation. This type of condition could be called dyspepsia Meckeli. It is believed that the heterotopic gastric mucosa secretes hydrochloric acid and pepsin and that the acid and pepsin become irritating to the ileum, producing spasms in the walls of the ileum and the diverticulum. These spasms, in turn, cause the symptoms. It is therefore recommended that when patients with such symptoms are seen dyspepsia Meckeli be considered and that at operation Meckel's diverticulum be excluded by searching for it.

Case 3 was interesting because simple excision of the bleeding diverticulum did not stop the hemorrhages and two days later it was necessary to resect a portion of the ileum to bring about the desired result.

Delay in operating in case 5, due to failure to recognize the inflammatory nature of the intestinal obstruction, led to a fatal outcome from peritonitis and septicemia. This was partly due to the fact that the patient was once successfully carried through a previous attack with the Miller-Abbott tube and to the fact that he seemed to improve under conservative treatment at the beginning of the last attack. No doubt, had operation been performed earlier the outcome of this case would have been different. It is possible that the occasional episodes of indigestion he had between the first and the last severe attack were due to dyspepsia Meckeli if not to peptic ulcer of the diverticulum.

Cases 9 and 10 were included to show that Meckel's diverticulum occurs without producing symptoms. If symptoms were present in these cases they were not recognized or were of subclinical intensity.

CONCLUSIONS

A general consideration of Meckel's diverticulum and of the 10 cases [44] reported here leads to the following conclusions: 1. If Meckel's diverticulum is suspected at all, early operation is imperative.

2. The treatment of Meckel's diverticulum is surgical removal of the diverticulum.

3. In a certain number of cases of Meckel's diverticulum there is probably a symptom complex resulting from secretion of hydrochloric acid and pepsin by heterotopic gastric mucosa, for which the term dyspepsia Meckeli is suggested.

44. Two additional cases (cases 11 and 12) were observed after this paper was originally written.

UTILIZATION OF OXYGEN BY THE BRAIN IN TRAUMATIC SHOCK

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Reduction in the effective volume of circulating blood in traumatic shock results in varying degrees of anoxia of the different structures of the body. The nervous system is probably more sensitive than other tissues to a deficit of oxygen and it is likely that irreversible changes take place there first. Many studies have been performed in recent years on metabolism and blood flow in the kidneys, the liver and other organs in shock. The brain has not received sufficient attention in this regard because of difficulties connected with methods for determining the cerebral blood flow and for collecting cerebral venous blood. These difficulties are to a considerable extent anatomic, in that the arterial blood is supplied to the brain through a number of different vessels. In the dog and the cat the external carotid arteries supply a considerable part of the total. As emphasized by Dumke and Schmidt,[1] the monkey resembles man in that the greater part of the cerebral blood flow is conducted by the internal carotid arteries and there are only insignificant communications between the intracranial and the extracranial part of the cephalic circulation.

The best method which has been devised for the direct determination of the blood flow of the brain is that of Dumke and Schmidt,[1] in which one uses a flowmeter after cannulation of the main cerebral arteries of the monkey. The only criticism of their method is that one may be dealing with a somewhat abnormal animal as a result of the experimental preparation itself. An extensive operation and systemic treatment of the blood with heparin are necessary for the conduct of the study. The present studies on dogs consisted of determinations of the oxygen content of arterial blood, of the oxygen content of venous blood obtained from the confluence of cerebral sinuses and of the total oxygen consumption of the animal after shock was produced by several different methods. It was appreciated at the initiation of these experiments that changes in the arteriovenous oxygen difference may not parallel alterations in the cerebral blood flow. At the same time it was hoped that information on the cerebral utilization of oxygen and the total oxygen consumption of the body would shed some light on the manner in which the brain responds to a reduction in blood volume, cardiac output and arterial blood pressure.

From the Department of Surgery of the Johns Hopkins University and Hospital. The work described in this paper was done under a contract, recommended by the Committee on Medical Research, between the Office of Scientific Research and Development and Johns Hopkins University.

1. Dumke, P. R., and Schmidt, C. F.: Quantitative Measurements of Cerebral Blood Flow in the Macacque Monkey, Am. J. Physiol. **138**:421, 1943.

METHODS

Dogs were used in all experiments. General anesthesia was produced approximately one hour before the control studies were performed by the intravenous injection of pentobarbital sodium, 25 to 30 mg. per kilogram of body weight. Subsequent subcutaneous injections were given as indicated, 5 to 10 mg. per kilogram of body weight. Samples of blood were collected under oil in 20 cc. syringes containing sodium oxalate. The oxygen consumption of the animal was determined by a Benedict spirometer. The approximate mean arterial blood pressure was determined by needle puncture of the femoral artery. The cardiac output was calculated by the Fick principle.

Arterial blood for the various analyses was obtained by puncture of the femoral artery. Mixed venous blood was withdrawn from the right auricle after a glass cannula was inserted through the right external jugular vein. Cerebral venous blood was obtained from the confluence of sinuses (torcular Herophili). The occipital protuberance was exposed, and an opening into it was made by means of a small drill. After blood escaped freely, a metal cannula was inserted. This cannula was 23 mm. in length. It had an external diameter of 4.5 mm. at the tip and an internal diameter of 1.5 mm. The distal end of the cannula was tapered and threaded in order to insure a snug fit into the bone. When blood was not being withdrawn, the cannula was plugged by an obturator.

The following methods were used in producing shock. In the experiments on hemorrhage, blood equal to 1 per cent of the body weight was removed at one hour intervals. Samples for the various analyses were withdrawn forty-five minutes after each bleeding. In the studies on burns the hair was clipped over the entire body. The deeply anesthetized animal was then dipped up to the axilla in water at 90 C. for ten seconds. In the experiments on the effects of trauma to an extremity, one of the thighs was struck approximately four hundred moderately severe blows with a hammer. In the studies on the effects of a tourniquet, a strong rubber tube was wrapped tightly about the uppermost part of each posterior extremity and was left in place for four hours before being removed.

RESULTS

Control experiments in which the oxygen content of the sinus blood was determined and other studies were performed over a six hour period showed no great alteration in the various factors during this time. All of the changes were much less marked than those which were found in the subsequent experiments.

All of the four experimental procedures for producing shock, hemorrhage, trauma, tourniquets and burns were associated with an increase in the arteriovenous difference of both the cerebral sinus blood and the mixed venous blood. The oxygen utilization of the cerebral sinus blood and that of the mixed venous blood in general paralleled each other closely. Particular attention is directed to the fact that the difference in oxygen content of the arterial blood and that of the sinus blood increased in the early stages of shock and this difference usually became more marked as shock developed. The early increase in the arterial-venous sinus oxygen difference was due in some instances to an increase in the oxygen content of the arterial blood rather than to a decrease in oxygen content of the venous blood. As indicated previously, the arterial–venous sinus oxygen difference usually increased before there was a significant decrease in the arterial blood pressure. Alterations in the total oxygen consumption of the body throughout the course of the experiments were not great. If one could assume that the oxygen consumed by the brain also remained essentially constant, the finding of an increased utilization of oxygen would mean that the cerebral blood flow was considerably reduced. Such an assumption is not warranted. The results of representative experiments are given in tables 1, 2, 3 and 4.

TABLE 1.—*The Effects of Graded Hemorrhage*

Time	Arterial Blood Pressure, Mm. Hg	Hematocrit Reading	Sinus Blood, Volumes per Cent: Carbon Dioxide	Sinus Blood, Volumes per Cent: Oxygen	Blood from Right Auricle, Volumes per Cent: Carbon Dioxide	Blood from Right Auricle, Volumes per Cent: Oxygen	Arterial Blood, Volumes per Cent: Carbon Dioxide	Arterial Blood, Volumes per Cent: Oxygen	Arteriovenous Difference, Volumes per Cent Oxygen: Sinus	Arteriovenous Difference, Volumes per Cent Oxygen: Right Auricle	Oxygen Consumption of Body, Cc. per Minute	Cardiac Output, Cc. per Minute	Blood Removed per Cent Body Weight	Comments
10:20 a.m. (control)	130	39.0	50.8	12.2	50.9	10.1	45.5	15.9	3.7	5.8	103	1,777	...	Weight 12.2 Kg.; pentobarbital sodium 30 mg. per Kg.
10:35	...	....	....	....	....	....	....	....	...	...	...	.....	1	Pentobarbital sodium 5 mg. per Kg.
11:20	133	42.4	45.7	11.7	45.6	13.2	40.6	18.2	6.5	5.0	107	2,140	...	
11:35	...	....	....	....	....	....	....	....	...	...	...	.....	1	Pentobarbital sodium 5 mg. per Kg.
12:20 p.m.	128	44.0	40.8	13.2	42.8	12.8	37.1	18.8	5.6	6.0	97	1,617	...	
12:35	...	....	....	....	....	....	....	....	...	...	...	.....	1	
1:20	120	41.8	41.4	8.2	40.0	7.0	31.6	18.2	10.0	11.2	106	946	...	
1:35	...	....	....	....	....	....	....	....	...	...	...	.....	1	
2:20	115	42.6	37.2	9.2	35.6	9.6	27.3	18.0	8.8	8.4	131	1,560	...	
2:35	...	....	....	....	....	....	....	....	...	...	...	.....	1	
3:20	48	38.9	32.3	5.5	32.8	4.2	18.3	16.7	11.2	12.5	114	912	...	
3:35	...	....	....	....	....	....	....	....	...	...	...	.....	1	
3:50	...	....	....	....	....	....	....	....	...	...	...	.....	...	Died

TABLE 2.—*The Effects of Trauma to An Extremity*

Time	Arterial Blood Pressure, Mm. Hg	Hematocrit Reading	Sinus Blood, Volumes per Cent: Carbon Dioxide	Sinus Blood, Volumes per Cent: Oxygen	Blood from Right Auricle, Volumes per Cent: Carbon Dioxide	Blood from Right Auricle, Volumes per Cent: Oxygen	Arterial Blood, Volumes per Cent: Carbon Dioxide	Arterial Blood, Volumes per Cent: Oxygen	Arteriovenous Difference, Volumes per Cent Oxygen: Sinus	Arteriovenous Difference, Volumes per Cent Oxygen: Right Auricle	Oxygen Consumption of Body, Cc. per Minute	Cardiac Output, Cc. per Minute	Comments
10:40 a.m. (control)	130	44.3	45.5	13.5	46.2	13.0	43.9	16.8	3.3	3.8	117	3,079	Weight 13.3 Kg.; pentobarbital sodium 28 mg. per Kg.
11:00-11:10	...	....	....	....	....	....	....	....	...	...	...	.....	Trauma to left leg
11:40	128	51.6	42.0	12.3	39.8	13.2	33.6	19.8	7.5	6.6	111	1,682	
12:50 p.m.	108	53.2	41.6	11.2	39.1	9.1	29.7	21.7	10.5	12.6	127	1,008	Pentobarbital sodium 10 mg. per Kg. subcutaneously
2:40	110	52.7	41.0	12.3	41.4	8.5	28.9	21.4	9.1	12.9	122	946	
4:40	80	51.3	37.4	11.2	38.8	10.0	27.6	21.5	10.3	11.5	115	1,000	3:30: pentobarbital sodium 10 mg. per Kg. subcutaneously
5:40	83	....	....	....	....	....	....	....	...	...	...	.....	Pentobarbital sodium 5 mg. per Kg. subcutaneously
7:40	70	50.7	35.5	9.0	35.4	6.7	23.9	21.0	12.0	14.3	114	798	
9:10	35	50.8	32.7	4.1	33.6	1.9	23.7	18.3	14.2	16.4	...	.....	
9:20	..	....	....	....	....	....	....	....	...	...	...	.....	Died

COMMENT

It is to be emphasized that the measurement of the quantity of oxygen which is removed from

each unit of blood which passes through the brain may not give a direct [2] indication of the cerebral blood flow. Schmidt and his associates stated the opinion that there is no correlation between the cerebral arteriovenous difference and the cerebral blood flow.

The present studies on utilization of oxygen by the brain are of interest in comparison with studies on other organs, particularly the kidneys, in shock. Van Slyke and his associates [3] found that the quantity of oxygen removed from each unit of blood passing through the kidney is not increased appreciably until peripheral circulatory failure has passed the initial stages and the blood flow through the kidney has been reduced to less than half of that in the preshock state. Bradburn and I [4] found a number of years ago that the oxygen content of blood in the renal vein was altered relatively little in various types of shock. It is to be noted in the present experiments that the arteriovenous oxygen difference in cerebral blood is usually considerably increased in the early stages of traumatic shock. Thus it appears that under conditions of decreasing blood flow the brain, unlike the kidneys, can maintain its oxygen consumption at least partially by extracting increased proportions of oxygen from the arterial blood.

TABLE 3.—*The Effects of Tourniquets*

Time	Arterial Blood Pressure, Mm. Hg	Hematocrit Reading	Sinus Blood, Volumes per Cent		Blood from Right Auricle, Volumes per Cent		Arterial Blood, Volumes per Cent		Arteriovenous Difference, Volumes per Cent Oxygen		Oxygen Consumption of Body, Cc. per Minute	Cardiac Output, Cc. per Minute	Comments
			Carbon Dioxide	Oxygen	Carbon Dioxide	Oxygen	Carbon Dioxide	Oxygen	Sinus	Right Auricle			
10:20 a.m. (control)	128	39.7	57.3	7.5	52.9	10.0	48.2	13.6	6.1	3.6	133	3,695	Weight 16.5 Kg.; pentobarbital sodium 25 mg. per Kg.
10:35	...	....	....	....	....	....	....	....	...	...	...	.....	Tourniquets on both hindlegs; 11:30: pentobarbital sodium 10 mg. per Kg. subcutaneously
12:35 p.m.	...	37.2	48.9	13.3	47.2	13.3	44.2	18.6	5.3	5.3	186	3,510	
2:30	143	49.8	45.5	13.5	43.0	14.3	39.3	20.0	6.5	5.7	150	2,632	
2:40	...	....	....	....	....	....	....	....	...	...	...	.....	Tourniquets removed
3:10	105	46.8	38.8	10.2	32.2	14.7	27.4	21.7	11.5	7.0	153	2,185	
4:10	90	50.3	37.1	10.3	33.8	13.9	25.2	23.4	13.1	9.5	150	1,578	
5:40	70	57.1	42.4	5.4	35.0	10.9	22.8	23.0	17.8	12.1	167	1,379	

TABLE 4.—*The Effects of Burns*

Time	Arterial Blood Pressure, Mm. Hg	Hematocrit Reading	Sinus Blood, Volumes per Cent		Blood from Right Auricle, Volumes per Cent		Arterial Blood, Volumes per Cent		Arteriovenous Difference, Volumes per Cent Oxygen		Oxygen Consumption of Body, Cc. per Minute	Cardiac Output, Cc. per Minute	Comments
			Carbon Dioxide	Oxygen	Carbon Dioxide	Oxygen	Carbon Dioxide	Oxygen	Sinus	Right Auricle			
10:40 a.m. (control)	128	48.1	48.5	13.8	50.1	11.6	47.1	15.9	2.1	4.3	95	2,208	Weight 14 Kg.; pentobarbital sodium 30 mg. per Kg. Burn 90 C. 10 seconds
11:00	...	....	....	....	....	....	....	....	...	...	...	.....	
11:05	90	52.0	43.3	15.7	43.1	14.4	37.6	20.3	4.6	5.9	88	1,492	
11:45	100	51.7	46.5	11.5	42.5	13.3	37.8	20.5	9.0	7.2	91	1,263	12:00: pentobarbital sodium 5 mg. per Kg.
1:00 p.m.	108	58.4	43.1	12.9	39.4	13.8	32.2	23.1	10.9	9.3	128	1,376	1:30: pentobarbital sodium 5 mg. per Kg.
3:00	113	....	....	....	....	....	....	....	...	...	...	.....	Pentobarbital sodium 5 mg. per Kg.
4:00	108	64.8	38.4	12.1	34.9	13.7	24.0	26.8	14.7	13.1	104	794	5:00: pentobarbital sodium 5 mg. per Kg.
7:00	78	69.8	34.1	10.0	30.0	13.6	17.2	28.4	18.4	14.8	109	737	
11:00	70	73.9	33.5	6.5	30.6	8.1	11.1	29.2	22.7	21.1	99	469	
11:55	..	....	....	....	....	....	....	....	...	...	...	.....	Died

Clarabelle Puryear and Vivien Thomas rendered valuable technical aid.

2. Schmidt, C. F.: Personal communication to the author, 1944.

3. Van Slyke, D. D.; Phillips, R. A., and others: Personal communication to the author, 1943.

4. Blalock, A., and Bradburn, H.: Distribution of the Blood in Shock, Arch. Surg. **20**:26 (Jan.) 1930.

TREATMENT OF TRAUMATIC ANEURYSMS AND ARTERIOVENOUS FISTULAS

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Traumatic aneurysms and arteriovenous fistulas were frequent sequelae of vascular injuries during the last great war and from current reports are even more numerous during the present war. This is not unexpected, for the type of armament now being used characteristically produces multiple wounds. Furthermore, in the past wounds of major blood vessels caused a high mortality as the result of hemorrhage, shock and infection. Now the presence of more highly trained medical officers in the forward areas, more rapid transportation and the use of large quantities of plasma and blood have greatly reduced the number of deaths from hemorrhage and shock. Also the combination of better surgical procedures performed earlier plus the use of sulfonamide compounds has resulted in a lower incidence of infection. The net result of these improvements is the survival of a larger number of soldiers with vascular injuries, in many of whom aneurysms and arteriovenous fistulas develop. It is therefore desirable to attempt to evaluate the various procedures used in the treatment of these important conditions. This task is undertaken in the present paper, which is based largely on a study of 29 patients who had vascular lesions caused by trauma. Thirteen had arteriovenous fistulas, 15 had arterial aneurysms, and 1 had an aneurysm of the abdominal aorta and a fistula between the aorta and the vena cava. When the patient last referred to was first seen the aneurysm had ruptured; so careful study was not possible, and the fistula was not localized at that time. It was treated later, independently of the aneurysm.

The physiologic effects of arterial aneurysms are less complex than those of arteriovenous fistulas. With an arterial aneurysm the effects are largely confined to the area supplied by the injured artery, whereas an arteriovenous fistula may produce profound effects on the entire circulatory system. This should be kept in mind in the management of the two conditions, but the same general principles are applied in the treatment of both.

A traumatic arterial aneurysm is usually the result of injury to an artery deeply embedded in the soft tissues, more often in an extremity or in the neck than in one of the great body cavities, for a wound of a vessel in one of the latter sites frequently results in fatal hemorrhage. The sequence of events usually is as follows: The weapon or missile penetrates the soft parts, including muscle and fascia, and then the artery. As the result of muscular contraction the tissue planes are shifted and the blood is trapped, forming a hematoma which communicates with the lumen of the artery. The blood in contact with the tissues clots, forming an irregular cavity which gradually becomes more or less spherical. In the early state the lesion is called a pulsating hematoma, but when it becomes well localized and spherical it is called a traumatic or false aneurysm. This paper is concerned with the latter condition.

It is generally agreed that once localization has occurred surgical intervention should be delayed to permit improvement in the collateral circulation and disappearance of bacteria from the adjacent tissues. Unless complications arise which demand earlier operation, conservative treatment should be continued for at least six to eight weeks. The developments most likely to indicate earlier operation are: increase in size of the aneurysm, causing compression of collateral channels or adjacent nerve trunks; infection, and secondary hemorrhage. Injury to important nerves at the time of the arterial injury also calls for operation as early as is compatible with reasonable safety.

The type of operation to be performeed is determined to a considerable extent by the presence or absence of complications and by the type of complication. As was pointed out by Elkin and Woodhall,[1] injury to important nerves in association with vascular lesions requires excision of the aneurysmal sac and repair of the nerves at the same operation whenever this is possible.

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1. Elkin, D. C., and Woodhall, B.: Ann. Surg. **119**: 411 (March) 1944.

This is desirable, but the interruption of nerve function by the pressure of an expanding aneurysm is not necessarily an indication for excision of the aneurysmal sac, for any procedure which relieves pressure, such as aneurysmorrhaphy, if performed early will be followed by return of nerve function. It is important, therefore, that a careful neurologic examination be done on any patient with a traumatic vascular lesion, especially when the subclavian, axillary, brachial or popliteal artery is involved. Not only should a primary neurologic examination be done, but this should be repeated whenever there is undue pain originating in the region of the aneurysm or when there is rapid enlargement of the aneurysmal sac.

Infection alone may be treated conservatively, but careful watch must be kept for secondary hemorrhage, and if it occurs immediate operation is indicated. The type of operation is dependent on the extent and severity of the infection as well as on the location of the aneurysm. If the infection is mild and especially if the aneurysm is so located that exposure of the artery proximal to the infection is difficult or fraught with unusual danger, the sac may be opened and the artery doubly ligated and completely divided between the ligatures. If, on the other hand, the artery can be readily exposed proximal to the area of infection and obstructed without interfering with essential collateral channels, proximal ligation of the artery and of the concomitant vein may be the treatment of choice. The following case report illustrates the value of proximal ligation of the artery and the vein under suitable conditions.

REPORT OF A CASE

W. A., a Negro man apparently about 35 years of age, entered St. Philip Hospital, Richmond, Va., Jan. 12, 1938, because of an infected wound of the lateral side of the left leg at the level of the knee. He had been stabbed ten days before and stated that there was profuse bleeding, which was controlled by external pressure. He was not confined to bed for the first few days, and approximately one week after the injury the leg became swollen and painful. Four days later he had a secondary hemorrhage. When he was admitted to the hospital there was slight bleeding from the wound, which was infected. There was marked swelling about the knee, and filling the popliteal space was a pulsating mass which extended laterally to the region of the stab wound. There was a systolic bruit over this mass. The other significant physical findings were as follows: A systolic murmur was heard at the cardiac apex and over the aortic area; the blood pressure was 170 systolic and 100 diastolic; the volume of the pulse in the posterior tibial and the dorsalis pedis artery was approximately equal in the two extremities, and the left leg and foot were warm.

The important laboratory findings were 2,800,000 red blood cells, 15,750 leukocytes, 84 per cent polymorphonuclear neutrophils and a positive Wassermann reaction of the blood and the spinal fluid.

Six days after admission to the hospital the patient had another hemorrhage so it was decided that proximal occlusion of the artery and vein had best be done. The femoral vessels were exposed in the adductor canal, and the artery was occluded by a strip of fascia and the vein ligated. Pulsation in the aneurysm promptly ceased and was not again noted. There was no further hemorrhage, and the wound healed satisfactorily. The posterior tibial and dorsalis pedis arteries no longer pulsated, but the collateral circulation was adequate. The patient was discharged from the hospital twenty-eight days after occlusion of the femoral artery. At the time of writing, six years later, he has no evidence of aneurysm and appears to have little difficulty with the circulation in the left leg and foot.

In another patient a false aneurysm of the proximal portion of the radial artery of five months' duration was cured by ligation of the terminal portion of the brachial artery. Although the result was satisfactory, aneurysmorrhaphy would have been a better procedure.

Proximal occlusion of the artery and the vein may be the procedure of choice under circumstances similar to those which developed in the first case. It may also be indicated when shrinkage must be caused in an aneurysmal sac to permit exposure of the vessels distally. In most other circumstances a more direct attack on the aneurysm should be employed.

CASES PRESENTED IN TABLE 1

Five patients with traumatic arterial aneurysms were treated by complete excision of the aneurysmal sac (table 1).

In the first patient represented in this table the median nerve was found to have been partially divided but healing seemed satisfactory except for an excess of scar; so the nerve was not resected. The radial nerve was moderately compressed but intact. The ulnar nerve was spread out to form a part of the wall of the sac, but when dissected away from the rest of the sac it appeared to be practically intact. At the time of writing, seventeen months later, there is no return of function in those fibers of the median nerve which supply the flexor digitorum profundus muscle, and sensation has not completely returned to that part of the hand which is supplied by the median nerve.

The case of patient 2 in table 1 is also of interest in that, according to the patient's history, only a small, hard mass persisted in the region of the stab wound until four weeks before he was admitted to the hospital, seventeen months after the injury. At that time the mass enlarged rapidly, producing severe pain and pronounced weakness of the muscles of the forearm and hand. On the patient's admission the mass was 5.5 by 4 by 4 cm. and did not pulsate. There was neither thrill nor bruit over it, and when the

sac was excised its lumen was completely filled with clot. The cords of the brachial plexus were firmly attached to the sac but showed no evidence of primary injury. This patient left the hospital on the fifth postoperative day, and even then there was considerable improvement in function of the muscles of the hand and the forearm. It has not been possible to examine him again.

No follow-up of patient 2 has been possible. Patient 3, a 14 year old boy, has not been examined recently, but his local physician states that he now, nine months after operation, has little disability of any kind. Since his common femoral artery was occluded, this result is of particular interest. The lumbar sympathetic nerves were interrupted by the injection of alcohol, and it is

TABLE 1.—*Traumatic Arterial Aneurysms Treated by Complete Excision of Sac*

Patient and Age	Involved Artery	Type of Injury; Duration	Result	Complications and Comment
1. N. B.* 26 yr.	Axillary artery, terminal portion	Bullet wound, 6 wk.	Aneurysm cured	Patient came to hospital because of severe pain and weakness of muscles of forearm; sac excised and nerves liberated; temporary weakness of all muscles of forearm; has recovered all motor function except flexion of distal joints of the index and middle fingers (median nerve)
2. J. H.* 27 yr.	Axillary artery	Stab wound; 1½ yr.	Aneurysm cured	Small mass persisted after injury and rapidly enlarged 4 weeks before coming to hospital; on admission radial pulse not palpable; marked weakness of muscles of hand and forearm; no gross nerve injury found; not possible to follow up
3. R. A.* 18 yr.	Deep volar arch	Stab wound; 3 wk.	Aneurysm cured	
4. W. D. 75 yr.	Superficial temporal artery	Blunt force; 3 wk.	Aneurysm cured	
5. V. M. 24 yr.	Radial artery	Stab wound; 3 wk.	Aneurysm cured	

* Wassermann reaction positive.

TABLE 2.—*Traumatic Arterial Aneurysms Treated by Aneurysmorrhaphy*

Patient and Age	Involved Artery	Type of Injury; Duration	Result	Complications and Comment
1. C. C.* 25 yr.	Abdominal aorta at level of inferior mesenteric artery	Bullet wound; 16 mo.	Aneurysm cured	Abdominal pain which became progressively more severe; patient also had physical signs of arteriovenous fistula within abdomen; see table 5 and case report 3
2. A. C. 29 yr.	Femoral artery in Hunter's canal	Bullet wound; 5 mo.	Aneurysm cured	Mild infection, temporary sinus formation; no appreciable interference with nutrition of lower part of leg and foot at time of discharge from hospital; claudication on fast walking
3. J. N. 14 yr.	Common femoral artery	Stab wound of artery, about ¾ divided in oblique direction; 10 days	Aneuryem cured	Early operation because of severe pain in distribution of femoral nerve; lumbar sympathetic nerves blocked with alcohol
4. J. J. 28 yr.	Axillary artery	Stab wound, artery almost completely divided; 1 mo.	Aneurysm cured	Operation necessary at end of 1 month because of rapid enlargement of aneurysm, causing serious interference with collateral circulation; pressure on cords of brachial plexus caused severe pain and weakness of muscles of arm and hand
5. E. W. 30 yr.	Profunda femoris artery, close to main trunk	Bullet wound; 5 mo.	Aneurysm cured	Opening in common femoral artery closed by suture; distal segment of profunda femoris artery ligated; circulation in main trunk not disturbed
6. R. W.† 45 yr.	Proximal portion of brachial artery	Stab wound; 6 wk.	Aneurysm cured	Patient entered hospital because of rapid increase in size of aneurysm, severe pain and rapid loss of function in all muscles of forearm; no gross nerve lesion demonstrated; postoperatively weakness of muscles supplied by radial nerve; anesthesia of index and middle fingers; patient signed release 5 days after operation
7. W. B.† 27 yr.	Distal portion of brachial artery	Stab wound; 7 wk.	Aneurysm cured	
8. R. A.† 23 yr.	Midportion of brachial artery	Stab wound; 1 mo.	Aneurysm cured	Impairment of sensation in distribution of median nerve; patient requested to return to outpatient clinic but failed to do so; no follow-up possible
9. W. L.† 36 yr.	Distal portion of brachial artery	Bullet wound; 13 mo.	Aneurysm cured	Temporary impairment of sensation in distribution of median nerve; complete recovery

* Previously reported in Ann. Surg. **112**: 879, 1940.
† Wassermann reaction positive.

CASES PRESENTED IN TABLE 2

Nine patients with traumatic arterial aneurysms were treated by aneurysmorrhaphy (table 2).

Unfortunately follow-up examinations have been possible in only a small number of these cases. In patient 1 there developed a severe ischemic neuritis with marked temporary disturbance of sensation and motion. Ligation of the vena cava probably would have prevented this complication.

possible that this circumstance is partly responsible for the satisfactory state of the circulation in the involved leg. The preservation of collateral channels incidental to aneurysmorrhaphy may also have played a part in the result.

Patient 4 now, five months after operation, shows complete return of motor function except for weakness of the biceps brachii muscle. It is probable that its nerve supply from the musculocutaneous nerve was injured at the time

of the vascular injury and that this was overlooked in the early neurologic examination.

The case of patient 5 illustrates the importance of determining whether or not the main artery is injured before occluding it. In this case the circulation in the femoral artery has remained intact, and there has been no disturbance in function.

Seven arteriovenous fistulas were treated by quadruple ligation and excision of the fistulous area (table 3).

TABLE 3.—*Traumatic Arteriovenous Fistulas Treated by Quadruple Ligation and Excision of the Fistulous Area*

Patient and Age	Involved Vessels	Type of Injury; Duration	Result	Complications and Comment
1. S. B. 46 yr.	Superficial femoral artery and vein, midportion	Bullet wound; 6 mo.	Cure of fistula	Visible pulsation in distal stump of femoral artery after resection and palpable pulse in both dorsalis pedis and posterior tibial arteries at completion of operation; in spite of this, involved leg tires rapidly, and foot is cold
2. E. W.* 18 yr.	Midportion of superficial femoral artery and vein	Bullet wound; 2½ mo.	Cure of fistula	Six weeks after operation leg measurements normal; no symptoms; follow-up not possible
3. A. H. 32 yr.	Common femoral artery and vein near level of profunda femoris artery	Bullet wound; 4 yr.	Cure of fistula	No immediate evidence of circulatory deficiency; no pulse in involved leg during hospital stay; his physician now, 7½ years later, reports weak pulse in popliteal and posterior tibial arteries; foot susceptible to cold; claudication on fast walking or on walking up hill; calf of leg 4 cm. larger than other (normal) leg
4. R. B. 24 yr.	Common femoral artery and vein	Bullet wound; 2 mo.	Cure of fistula	Postoperatively weak dorsalis pedis pulse; 3 years later weak pulse in dorsalis pedis and posterior tibial arteries; foot cold; slight swelling of leg; claudication on walking 2 blocks
5. S. W. 38 yr.	Popliteal artery and vein	Bullet wound; 14 yr.	Cure of fistula	Vein proximal to fistula approximately three times size of vein distal to fistula; ulcer on anteromedial surface of lower part of leg of 3 months' duration at time of operation; healed slowly; then broke down again in 1942—5 years later; healed again; then recurred 1 year later; unable to make examination at this time
6. C. A. 16 yr.	Popliteal artery and vein	Bullet wound; 8 mo.	Cure of fistula	Dorsalis pedis pulse present (small volume) after resection of vessels; now, 7 years after operation, in army hospital awaiting discharge because of swelling and rapid tiring of leg; complains of coldness of foot
7. J. M.* 28 yr.	External carotid artery and posterior facial vein	Stab wound; 5 yr.	Cure of fistula	Two days after operation a systolic bruit heard anterior to auditory canal; cause undetermined; follow-up not possible

* Wassermann reaction positive.

TABLE 4.—*Traumatic Arteriovenous Fistulas Treated by Repair of Artery*

Patient and Age	Involved Vessels	Type of Injury; Duration	Result	Complications and Comment
1. C. S.* 58 yr.	Common carotid artery and internal jugular vein	Stab wound; 23 mo.	Cured	Patient examined May 8, 1944, 10½ years later; has remained well; carotid artery has remained patent
2. R. B. 55 yr.	Common carotid artery and internal jugular vein	Bullet wound; 37 yr.	Remained well for 2 yr. and 8 mo.; then false aneurysm developed	Obliterative aneurysmorrhaphy for false aneurysm; proximal and distal ligation of artery; recurrent hemorrhage finally caused death; see report of second case reported
3. C. P. 19 yr.	Common femoral artery and vein	Bullet wound; 6 wk.	Cured	At operation fistula between artery and vein was divided, and openings in artery and vein were closed by fine silk sutures; false aneurysm, lateral side of artery and about 2 cm. in diameter, resected and artery repaired; artery and vein remained patent; 3 years later no demonstrable difference in circulation in two extremities

* Surgery **2**: 555, 1937.

CASES PRESENTED IN TABLE 3

Excellent immediate results were obtained in the 7 patients represented in this table, but the late results are less satisfactory. In 1 patient there was no evidence of circulatory deficiency at the end of six weeks, but a late follow-up was not possible. In 5 other patients, in whom important vessels of the extremities were also involved, there is definite evidence that the circulation is inadequate for sustained muscular activity. This is an important matter and one which has not received the attention which is its due.

CASES PRESENTED IN TABLE 4

Three traumatic arteriovenous fistulas were treated by repair of an artery (table 4).

R. E. B., a white man 55 years of age (table 4, patient 2), was admitted to the Medical College of Virginia Hospital, Richmond, Va., April 3, 1940, complaining of shortness of breath and progressive loss of strength. Thirty-seven years before this he had received a bullet wound in the right side of his neck, and since then he had noted a pulsating mass at the site of injury. Examination showed a small pulsating mass in line with the carotid artery and the internal jugular vein at the level of the thyroid cartilage. There was a loud, continuous, machinery-like murmur over this mass, radiating along the course of these vessels.

The blood pressure was 180 systolic and 80 diastolic. Pressure over the fistula caused slowing of the pulse from 80 to 66. The cardiothoracic ratio was 57 per cent. At operation the aforementioned artery and vein were found separated by a false aneurysm about 2.5 cm. in diameter, through which they communicated. The vein was ligated proximal and distal to the fistula; the aneurysm was opened widely, and the opening in the artery, which was surrounded by a heavy deposit of calcium, was closed by interrupted mattress sutures of fine silk. The aneurysmal sac was obliterated by silk sutures and the vein used to cover the area of repair.

The morning after the operation the patient's blood pressure was 200 systolic and 110 diastolic and the cardiothoracic ratio 56 per cent.

Ten days later the blood pressure was 155 systolic and 95 diastolic and the cardiothoracic ratio 51 per cent. Recovery was uneventful.

Two years and eight months later a false arterial aneurysm developed at approximately the site of repair of the arteriovenous fistula. The aneurysm enlarged rapidly and caused severe pain; so the artery was exposed proximal to the aneurysm and occluded by a strip of fascia. The tenseness of the mass and the force of the pulsations were diminished for only a few days. There was no evidence of interference with the cerebral circulation; so the carotid artery was ligated distal to the aneurysm, and the sac was incised, the clot evacuated and the opening in the artery sutured (obliterative aneurysmorrhaphy). The vessel was extremely sclerotic, and there was moderate bleeding when the clot was evacuated, indicating that the fascial occlusion was no longer complete. Because of the marked degree of sclerosis, it was feared the sutures might give way; so a ligature was applied adjacent to the strip of fascia. A low grade infection developed, however, and the ligature cut through, causing secondary hemorrhage. Repeated attempts were made to control the bleeding, including a transpleural ligation of the innominate artery, but in the exposure of this vessel an infected hematoma was entered, empyema developed and finally the ligature of the innominate artery cut through, with fatal hemorrhage.

While the results in 2 of the cases presented in table 4 were excellent, the unfortunate outcome in the other case may justifiably raise doubt as to the value of arterial repair. In reality the result in the third case should be attributed to the misapplication of a procedure and not to the procedure itself, for the presence of heavy deposits of calcium in the wall of the artery was a definite contraindication to suture of the arterial end of the fistula. Suture was carried out in spite of this because it was feared that resection of the fistulous area would result in inadequate cerebral circulation. Proximal and distal ligation of the vein and subtotal occlusion of the artery by a strip of fascia as a preliminary procedure, followed by excision of the fistulous area when it had been established that there was an adequate collateral circulation, would have been the method of choice.

TABLE 5.—*Traumatic Arteriovenous Fistulas Treated by Atypical or Incomplete Operative Procedures*

Patient and Age	Involved Vessels	Type of Injury; Duration	Operative Procedure	Complications and Result
1. L. R.* 32 yr.	External iliac artery and vein	Bullet wound; large traumatic aneurysm extending into pelvis and apparently not immediately connected with fistula; 9 mo.	Ligation of external iliac artery, common iliac vein and common femoral vein; fine silk sutures passed through wall of unopened vein to close opening in artery	Bruit with marked systolic accentuation detected 13 days after operation; arterial aneurysm did not pulsate; local physician states there is now little demonstrable difference in legs, but involved leg tires more rapidly; no swelling; preoperatively swelling was marked
2. C. C.† 25 yr.	Abdominal aorta and inferior vena cava	Bullet wound; 3 yr. and 8 mo.	Aorta ligated with cotton tape proximal to fistula; fistula closed with silk sutures passed through wall of unopened vena cava	Fistula remained closed; tape cut through wall of aorta 3 months after ligation, causing fatal hemorrhage; see accompanying report
3. L. M. 18 yr.	Posterior tibial artery and vein	Bullet wound; 4 wk.	Ligation of artery and vein proximal to fistula	Fistula not found; bruit disappeared after ligation of posterior tibial artery and vein and did not recur while patient was under observation, approximately 10 weeks; no late follow-up possible
4. R. J. 10 yr.	Distal portion common carotid artery and internal jugular vein	Bullet wound; artery and vein communicated through false aneurysm sac which overlay proximal portion of both internal and external carotid arteries; 14 mo.	Ligation of vein proximal and distal to fistula; occlusion of common carotid artery proximal to fistula by strip of fascia	Artery occluded proximal to aneurysm with hope of reducing size of sac, thereby making exposure of the internal carotid artery less difficult; second operation unnecessary; aneurysm and fistula well 3 years and 8 months after operation

* Wassermann reaction positive.
† Ann. Surg. **112**: 879, 1940.

CASES PRESENTED IN TABLE 5

Four arteriovenous fistulas were treated by atypical or incomplete operative procedures (table 5).

C. C., a white man 25 years of age at the time of this, his first, admission (table 5, patient 2), was operated on Dec. 14, 1938, in the Memorial Hospital, Richmond, Va., for a ruptured aneurysm of the distal portion of the abdominal aorta.[2] At operation, before the aorta was occluded, a continuous thrill of the type found with arteriovenous fistulas was noted in the region

2. Bigger, I. A.: Surgery **112**:879 (Nov.) 1940.

adjacent to the aneurysm, but because of difficult circumstances a careful search was not possible, and the site of the fistula was not discovered. After occlusion of the aorta the thrill disappeared, and it had not reappeared one month later, when the abdomen was reentered for repair of the opening between the aneurysm and the aorta. A faint thrill and a bruit were noted five months later, and one year after the aneurysmorrhaphy both thrill and bruit had become pronounced and were most distinct just to the right of the midline, 4 cm. above the level of the umbilicus. The heart was not enlarged.

When the patient was again examined, in January 1941, the thrill and the bruit were intense and radiated downward on the right to the inguinal ligament but not beyond, a fact which seemed to point to the mesenteric vessels as the site of the fistula. For several months the patient had complained of increasingly severe pain in the lower part of the abdomen, and it had been necessary to give him morphine repeatedly. Roentgen ray examination of the spine and of the gastrointestinal tract gave negative results save for a moderate degree of stenosis of the third portion of the duodenum. This was attributed to scar, as that portion of the duodenum had been freed for exposure of the aorta at operation for rupture of the aneurysm.

A few days after this examination the patient returned to the hospital because he had fainted, and it was feared that the aneurysm had recurred and had again ruptured. Nothing was discovered to explain the abdominal pain; so exploratory laparotomy was performed on March 4, 1941. A very pronounced thrill was present along the right side of the terminal portion of the aorta, and a fistula was found between the aorta and the vena cava just below the level at which aneurysmorrhaphy had been done. There was no recurrence of the arterial aneurysm. There were many intra-abdominal adhesions, and these were especially dense between the left side of the colon and the adjacent structures. The third part of the duodenum was constricted by scar and was freed. The aorta and the vena cava were firmly adherent to each other. They were liberated proximal to the fistula. During an attempt to dissect out the vessels distally so as to be able to control the circulation during repair of the fistula, the right common iliac vein was torn. The hemorrhage was profuse and difficult to control. The aorta was ligated above the fistula with cotton tape and the rent in the vein closed by silk sutures. The vena cava was also ligated. The patient showed moderate shock; so no attempt was made to close the fistula. After this operation there was no evidence of circulatory deficiency in the lower extremities. This was especially interesting, for after the previous occlusion of the aorta the circulation in the lower extremities was seriously disturbed. No doubt the chief factor in the maintenance of a satisfactory supply of blood to the lower extremities after the second occlusion of the aorta was obstruction of the vena cava proximal to the fistula.

Eight weeks after ligation of the aorta and the vena cava the fistula was closed with mattress sutures of fine silk, which were passed through the anterolateral wall of the vein, the anterior margin of the opening in the aorta, the posterior margin and the posterolateral wall of the vein and then back in the reverse order. The thrill and the bruit disappeared and did not recur. The patient continued to complain of severe abdominal pain but otherwise made a satisfactory recovery and was discharged from the hospital May 6, 1941, two weeks after operation.

Three and one-half months after ligation of the aorta and six weeks after closure of the fistula there was a massive hemorrhage into the duodenum, and death occurred approximately twenty-four hours later.

Autopsy showed that the tape had cut through the wall of the aorta, which then ruptured into the third part of the duodenum. Both the arteriovenous fistula and the arterial aneurysm appeared to be well healed (see figure). Nothing was found to explain the severe abdominal pain.

Although 2 of the 4 patients referred to in table 5 were apparently cured by atypical or incomplete operations, it is evident that frequent failures are to be expected. It seems reasonable, therefore, to state that complete ligation of the vessels and excision of the fistulous area or suture of the arterial opening should be done in one stage unless there are excellent reasons for some other procedure's being followed. In the case of patient 1 the presence of a very large false aneurysm in an area difficult of approach was considered sufficient justification for not excising the aneurysm and the fistula. The vein was therefore ligated both above and below the fistula, which was then closed with mattress sutures of fine silk inserted through the wall of the unopened vein. Arterial repair under direct vision through the opened vein would have permitted more accurate placement of the sutures, and since the vessels could readily have been temporarily occluded both proximally and distally, this would have been the procedure of choice. The continuous thrill and bruit disappeared when these sutures were tied, but pulsation in the large aneurysm persisted. Pressure on the external iliac artery above the aneurysm obliterated this pulsation, while pressure on the internal iliac artery had no effect on it. The external iliac artery was therefore ligated above the aneurysm but not below it, for it was feared that the latter procedure might seriously interfere with the supply of blood to the extremity, since the inferior epigastric and deep circumflex iliac branches would have been included in the obstructed area. However, since the blood supply to the extremity remained entirely adequate, it is improbable that obstruction of these two arteries would have caused more than transient ischemia. The plan was to produce shrinkage of the aneurysm by proximal obstruction of the artery and then excise the aneurysm at a second operation, but the patient refused to be operated on again. It has not been possible to examine this patient since she left the hospital, but her local physician states that there is now, fourteen months later, little demonstrable difference in the extremities. Swelling, which was marked preoperatively, is no longer present. The condition of the aneurysm is not known.

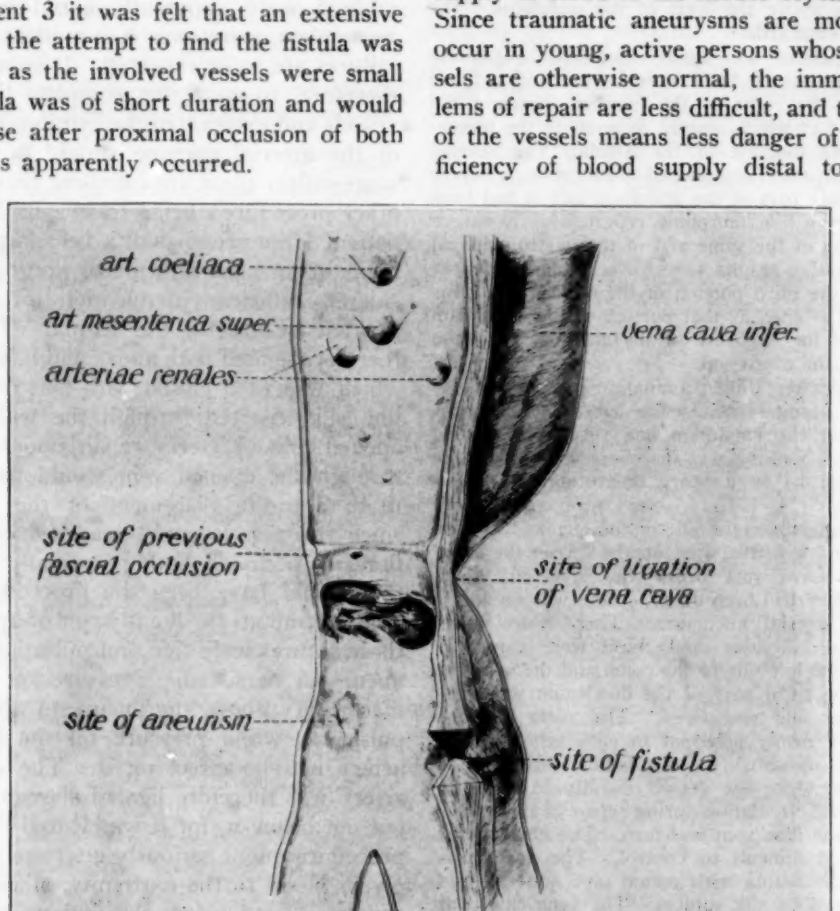
With patient 2 the obvious mistake was the use of tape rather than fascia to occlude the aorta.

Had fascia been used this patient should have survived with the fistula closed and with eventual reopening of the lumen of the aorta. The blind repair of the fistula was justifiable because of the difficulty encountered in isolating the vessels, and this would have been necessary so as temporarily to obstruct them for repair under direct vision.

With patient 3 it was felt that an extensive dissection in the attempt to find the fistula was unjustifiable, as the involved vessels were small and the fistula was of short duration and would probably close after proximal occlusion of both vessels. This apparently occurred.

COMMENT

The treatment of a traumatic arterial aneurysm does not differ in principle from the treatment of a spontaneous aneurysm when important vessels of the neck and extremities are involved. The goal to be achieved in both is cure of the aneurysm with minimum interference with the supply of blood to the tissues beyond the lesion. Since traumatic aneurysms are more likely to occur in young, active persons whose blood vessels are otherwise normal, the immediate problems of repair are less difficult, and the reactivity of the vessels means less danger of acute insufficiency of blood supply distal to the lesion.



Drawing of the aorta and vena cava from case 2, table 5, showing the site at which the tape cut through. The drawing also shows healing at the site of the aneurysm and the arteriovenous fistula.

In the case of patient 4 the plan was to bring about shrinkage of the false aneurysmal sac so as more safely to expose the bifurcation of the carotid artery at a second operation and thus gain control of the circulation before attempting to repair the fistula. At the same time the collateral circulation was tested and proved adequate. If excision of the fistulous area had become necessary there would have been no fear that this would cause serious cerebral anemia. The fistula closed, the aneurysm was cured and the carotid artery is now patent throughout. This result was as unexpected as it was satisfactory.

On the other hand, it is more important to maintain normal blood supply in young persons than in persons with generalized vascular disease, which is so frequently present in patients who have spontaneous aneurysms.

Therefore, in young men with traumatic vascular lesions of important blood vessels the surgeon not only must give thought to the cure of the lesion and to the prevention of acute ischemia and gangrene but must also consider the late effects on the blood supply to the part. In the literature dealing with the treatment of such lesions much is said, and properly, about the cure of the lesion and the avoidance of acute

ischemia and gangrene, but remarkably little consideration is given to the permanent reduction of blood supply to the tissues, especially the muscles, distal to the lesion.

Makins [3] in his Bradshaw Lecture discussed this problem and stated that Frisch examined 10 patients in whom the main arteries to extremities had been tied from one to eight years previously. In only 4 of the 10 could the limbs be considered sound, while in the remaining 6 there were trophic changes of varying degree. Makins also referred to work done by Karotkoff, who estimated the peripheral blood pressure in 17 patients in whom main arteries had been ligated. In 7 the pressure was less than one-half that in the sound limb, in 4, about one-half and in 4 more than one-half; in only 2 was the pressure equal to that in the sound limb.

Of the patients reported on in this paper there were 3, patient 3 in table 2 and patients 3 and 4 in table 3, in whom the common femoral artery was permanently occluded and 1, number 1 in table 5, in whom the external iliac artery was ligated. In 2 of these patients, both of whom had the vessels ligated and resected for arteriovenous fistulas, the involved extremity now tires quickly, especially on rapid walking or walking up hill. The third patient had the fistula closed by suture, the artery ligated proximally, and the vein ligated both proximally and distally. This patient also states that the affected leg tires rapidly. The fourth patient, a 14 year old boy, apparently has few symptoms of circulatory deficiency in the involved extremity at the time of writing, eight months after the operation. It may be significant that this boy had a chemical (alcohol) section of the lumbar sympathetic nerves. Gage and Ochsner [4] have shown that this procedure is of great value in the prevention of ischemic gangrene. It may be that when the main artery to an extremity is ligated sympathectomy will also prevent the chronic circulatory deficiency so frequently encountered under such circumstances. Another factor which may have played a part in the good functional result in this boy is the preservation of collateral channels by the use of aneurysmorrhaphy.

Two patients who had resection of the popliteal vessels for arteriovenous fistula have serious disturbance of the circulation in the involved extremities. One has had recurrent ulcers of the leg, and the other is now a patient in an army hospital awaiting discharge from the army because of inadequate circulation in the affected leg. Of the 3 patients in whom the superficial femoral artery was occluded a late follow-up has been possible with only 1. This patient states that the involved leg tires more quickly than the other leg and that he suffers constantly from coldness of the foot.

With an arterial aneurysm there is only moderate danger of gangrene if operation is delayed until the collateral circulation has been established, even though the sac is completely excised and collateral channels are thereby sacrificed. For a traumatic aneurysm with associated lesions of important nerves, excision of the aneurysmal sac is indicated, for this procedure permits examination and repair of the injured nerves; but when there is no especial indication for excision of the sac and no contraindication to aneurysmorrhaphy the latter is the operation of choice. When restorative aneurysmorrhaphy is possible, cure may be obtained with little interference with the circulation, and even when obliterative aneurysmorrhaphy is performed the distal circulation is disturbed less than when the sac is excised, because fewer collateral channels are sacrificed. The simplicity of the Matas operation and the saving of collateral channels are important advantages.

In a patient with an arteriovenous fistula a remarkable collateral circulatory bed develops and there is little danger of ischemic gangrene after resection of a main artery, even the common femoral or popliteal, but such a patient appears to be as prone to chronic circulatory difficulty as one having ligation of a corresponding vessel for arterial aneurysm. In the patients here reported on in whom a main vessel was resected for arteriovenous fistula there was no instance of serious acute circulatory difficulty, but all of them have evidence of persistent circulatory deficiency.

In spite of this undesirable effect, it seems to be the consensus of most writers that ligation of the artery and the vein and excision of the fistulous area is the procedure of choice in the treatment of an arteriovenous fistula, and Elkin and Woodhall made the following statement: "Moreover, the eradication of an arteriovenous fistula is accomplished only by quadruple ligation and excision. Any other method usually results in recurrence."

There is no doubt that quadruple ligation and excision result in the highest percentage of cures. However, in properly selected cases the Matas operation, proximal and distal ligation of the vein plus transvenous repair of the artery, under

3. Makins, G. H.: The Bradshaw Lecture: Gunshot Injuries of the Arteries, London, Oxford University Press, 1914.

4. Gage, M., and Ochsner, A.: Ann. Surg. **112**: 938 (Nov.) 1940.

direct vision, will cure a high percentage of patients with minimum disturbance of the circulation.

SUMMARY

Twenty-nine cases of traumatic arterial aneurysm or arteriovenous fistula have been studied. Unfortunately, satisfactory follow-up studies have not been possible in a considerable number of cases but it is believed that evidence of some value has been obtained regarding the occurrence of subjective symptoms of chronic circulatory deficiency after obstruction of main arteries of the extremities. Eight of 9 patients in whom one of the main arteries to the lower extremity was obstructed had follow-up examinations at periods of from nine months to eight years after operation. Seven of them have definite symptoms of chronic circulatory deficiency distal to the obstruction.

Excision of an aneurysmal sac is more certain to cure the lesion than aneurysmorrhaphy but has the disadvantage of destroying more collateral channels than does the intrasaccular operation. It is reasonable to assume that interference with the collateral arteries would increase the danger of ischemic gangrene and would also increase the degree of chronic circulatory deficiency.

An atypical or incomplete operation may result in cure of a traumatic aneurysm, but an arteriovenous fistula is rarely cured except by complete ligation of the involved vessels and excision of the fistulous area or by suture of the artery. If the latter procedure is employed it is usually better to ligate the vein above and below the fistula and then to open the vein and suture the artery under direct vision.

Evidence is also presented which indicates that while the excellent collateral circulation developed in the presence of an arteriovenous fistula makes the danger of ischemic gangrene almost negligible, it does not prevent persistent circulatory difficulty when main vessels are ligated and resected. It is therefore suggested that when such important vessels as the carotid artery and jugular vein, the common femoral vessels or the popliteal vessels are the site of arteriovenous fistula transvenous repair of the artery be employed if there are no contraindications. The most important contraindication to arterial suture is calcification of the wall of the artery in the area to be sutured.

When main vessels are obstructed, especially those to the lower extremity, permanent interruption of the sympathetic nerves to that extremity may help prevent chronic circulatory deficiency distal to the obstruction.

ABSTRACT OF DISCUSSION

DR. JOHN DEJ. PEMBERTON, Rochester, Minn.: In many cases it is essential that preliminary measures be undertaken before the blood flow of a main artery is interrupted. These measures are directed toward (1) enlarging the capacity of the secondary channels by prolonged intermittent compression of the artery proximal to the site of the aneurysm (Matas) or by partial compression of the artery by means of bands and (2) reducing the peripheral resistance to blood flow by means of sympathectomy. For an arteriovenous fistula of at least several months' duration, these preoperative measures are seldom necessary, because the presence of the arterial fistula, as was pointed out by Mont Reid, serves as a powerful stimulant to the development of collateral circulation. In addition to preliminary measures, another measure is sometimes needed in order to maintain the collateral circulation, that is, the use of anticoagulants to prevent the formation or propagation of a clot in the artery distal to the point of blockage. With the possible exception of fistulas involving the carotid artery and the cavernous sinus, the complete occlusion of the internal carotid artery in the neck is always fraught with two principal dangers: (1) anemia of the brain due to inadequate collateral circulation, arising perhaps from anomalies of the circle of Willis, and (2) secondary thrombosis or embolism in the distal segment of the carotid artery and its branches. Cerebral disturbances due to cerebral anemia become manifest immediately after the occlusion of the artery, whereas in cases of thrombosis there is an interval of hours or even days between the operation and the manifestation of the cerebral disturbances. The cause of the clotting is probably a combination of factors—stagnation of blood in the distal segment of the carotid artery and injury of the intima at the site of occlusion. This complication was first impressed on me in 1933, when I operated on a woman 39 years of age for a malignant tumor of the left carotid body, which had infiltrated into the surrounding tissues and onto the walls of the internal and external carotid arteries. To remove the tumor it was necessary to excise segments of the common, external and internal carotid arteries. The postoperative course was satisfactory for forty hours; then hemiplegia developed, and the patient was unable to speak or swallow. Bronchopneumonia supervened, and she died on the sixth postoperative day. Necropsy revealed thrombosis extending into the left middle cerebral artery with infarction of the left parietal lobe of the brain. Since then this complication has occurred in 2 other patients in my service, but with happier results. One was a man 21 years of age who was operated on Jan. 29, 1943 for a tumor of the left carotid body. Exposure revealed a large (4 by 3 by 3 cm.), firm, infiltrating tumor which was adherent to the surrounding structures, including the walls of the carotid arteries. After examining a specimen removed from the tumor the pathologist reported a malignant tumor of the carotid body. The tumor then was excised, together with segments of the external, internal and common carotid arteries. Twelve hours later the patient seemed drowsy and the movements of the right arm and leg were less than those of the left side. The movements of his eyes were normal. Intravenous administration of heparin was started immediately, and 300 mg. of dicoumarin (3,3'-methylenebis-[4-hydroxycoumarin]) was administered by means of an intranasal tube. On the third postoperative day the prothrombin time was estimated to be seventy-one seconds and the administration of heparin was stopped. The administration of

dicourmarin was continued in doses sufficient to maintain the prothrombin time at more than thirty-five seconds, as determined by daily estimations, for two weeks. On the fourth postoperative day the patient was able to swallow and his state of consciousness was practically normal. He, however, was unable to speak, although he seemed to understand the spoken word. General improvement continued, and when he was dismissed from the clinic on the twenty-seventh day his right arm was still partially paralyzed and he was able to say only a few words. Six months later examination revealed remarkable improvement, but he still had slight difficulty in speech and slight weakness in his right hand. The second patient was a man 43 years of age, who was operated on Oct. 30, 1942 for a fusiform aneurysm of the first portion of the right internal carotid artery, which measured about 3.5 by 2 by 2 cm. As a preliminary procedure the common carotid artery was partially compressed by a fascial band and the external carotid artery was ligated. Convalescence was normal. The patient returned four months later for the second procedure. About ten hours prior to an obliterative endoaneurysmorrhaphy he was given 300 mg. of dicoumarin. Convalescence was satisfactory for about twenty-two hours, after which time he suddenly complained of loss of sight in his right eye. The pupil did not react to light, and examination of the fundus revealed closure of the central retinal artery, with considerable narrowing of all its branches. Administration of heparin was started, and treatment with dicourmarin was continued. On the third postoperative day examination revealed good blood flow through many of the retinal arteries and all the veins and improvement in the patient's vision. At the time of the patient's dismissal, about two weeks after operation, vision in his right eye was about 40 per cent. It is my belief that extensive thrombosis was prevented in both patients by the use of anticoagulants and that thrombosis could probably have been prevented altogether if heparin had been administered immediately at the conclusion of the operation. I am convinced that the administration of anticoagulants is definitely indicated in all cases in which operative occlusion of the internal or common carotid artery has been performed and perhaps also in cases in which other main arteries are involved. Such anticoagulant therapy is especially needed in cases in which the sufficiency of the collateral circulation is in doubt. These drugs should be so administered that their full anticoagulant value will be effective immediately after the operation and will be maintained for ten to twelve days thereafter.

Dr. Waller Overton Bullock, Lexington, Ky.: The subject is "traumatic aneurysms." I wish to say that pulsating hematoma, false aneurysms and true aneurysms are all the same. The only difference is in time. It is my view that a traumatic aneurysm is a clot with a cavity in it, lined with endothelium and connected with a blood vessel, a result of injury. The essential thing in the treatment of this condition is to discover it as early as possible, not to wait until the aneurysm develops. In the early stages the pulsating tumor in a wound and extravasation will be present. When these are noted repair work should be done immediately, before the aneurysm develops. The bruit and other characteristic sounds may not appear until later. Many aneurysms can be prevented in the future by early attention to the symptoms that are the result of injuries to the vessels and by immediate repair.

Dr. I. A. Bigger, Richmond, Va.: [In closing the discussion Dr. Bigger emphasized some of the points in his summary.]

SURGICAL TREATMENT OF HYPERTENSION

THE EFFECT OF RADICAL (LUMBODORSAL) SPLANCHNICECTOMY ON THE HYPERTENSIVE STATE OF ONE HUNDRED AND FIFTY-SIX PATIENTS FOLLOWED ONE TO FIVE YEARS

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The series of 156 hypertensive patients whose cases are considered in this paper were operated on during the past five years and followed for one to five years. The preoperative resting diastolic blood pressure levels ranged from 100 to 162 mm. of mercury. There were 92 women and 64 men. The average age of the women was 35 and of the men 40 and of the entire series 37. The ages ranged from 16 to 57 years.

Included are 11 patients with pyelonephritis [1] and 1 with polycystic kidneys. They have done unusually well. Three patients with adrenal tumors,[2] cortical or medullary, which in retrospect appeared to be dominant factors in the hypertensive state are excluded. On the other hand, 6 patients with adrenal tumors which did not appear to have been of major importance are included. All of these had cortical adenomas, which, like all of the tumors, were unexpectedly found at operation. In some of the cases of pyelonephritis also the condition was found at operation, and the polycystic kidneys previously mentioned were likewise detected in this way. None of the patients with adrenal tumors had paroxysmal hypertension. This series, then, aside from these exceptions, is largely composed of patients with hypertension of all degrees of severity without known primary disorders of the kidneys or adrenal glands. One can, however, gather an approximate idea of the possible incidence of such disorders in a group of hypertensive patients of this size.

The operation, lumbodorsal splanchnicectomy,[3] is more extensive than other operations [4] which have been performed for the relief of hypertension with the exception of the total or near-total sympathectomy of Grimson.[5] Its purpose is to insure a thorough denervation of the visceral vascular bed. A study of the possible origin of the vasomotor nerve supply to this area in man indicates that it is diffuse. Potentially important pathways may arise from the sympathetic trunks from the third dorsal to the second lumbar segment inclusive and reach the splanchnic bed in a manner which varies considerably from patient to patient and even on the two sides of the same patient. It was clearly demonstrated by multiple stage operations on hypertensive patients that failure to modify the hypertension in a given patient could be due to inadequate surgical operation.[3] A failure to decrease the hypertension following a lesser operative procedure can be converted into a successful result by removing more extensive portions of the sympathetic trunks in subsequent stages.[3] Similar experiences were reported by deTakáts and his associates [6] and by Ayman and Goldshine.[7] It was also demonstrated that near-total sympathectomy could fail to modify the hypertensive state significantly.[5]

Since these pathways arise both above and below the diaphragm, a transdiaphragmatic approach was used in this series, the inner portions of the eleventh and twelfth ribs being resected through a paravertebral incision. In all cases

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1. These patients together with others will be reported on separately as well.

2. These patients together with 1 other will be reported on separately.

3. Smithwick, R. H.: A Technique for Splanchnic Resection for Hypertension, Surgery **1**:1-8, 1940.

4. Adson, A. W., and Brown, G. E.: Malignant Hypertension: Report of Case Treated by Bilateral Section of Anterior Spinal Nerve Roots from the Sixth Thoracic to the Second Lumbar, Inclusive, J. A. M. A. **102**:1115-1118 (April 7) 1934. Craig, W. M.: Surgical Approach to and Resection of the Splanchnic Nerves for Relief of Hypertension and Abdominal Pain, West. J. Surg. **42**:146-152, 1934. Peet, M. M.: Splanchnic Section for Hypertension: A Preliminary Report, Univ. Hosp. Bull., Ann Arbor **1**:17-18, 1935. Crile, G.: Genesis and Surgical Treatment of Essential Hypertension, Pennsylvania M. J. **40**:1017-1020, 1937.

5. Grimson, K. S.: Total Thoracic and Partial to Total Lumbar Sympathectomy and Celiac Ganglionectomy in Treatment of Hypertension, Ann. Surg. **114**: 753-775, 1941.

6. deTakáts, G.; Heyer, H. E., and Keeton, R. W.: The Surgical Approach to Hypertension, J. A. M. A. **118**:501-507 (Feb. 14) 1942.

7. Ayman, D., and Goldshine, A. D.: Blood-Pressure Determinations in Patients with Essential Hypertension, New England J. Med. **229**:799-811, 1943.

the great splanchnic nerves were removed from the semilunar ganglion to the midthoracic level or higher. Various portions of the sympathetic trunks were excised. The minimal operation included removal of the tenth thoracic to the first lumbar ganglions inclusive, and the maximal, excision of the sixth thoracic to the third lumbar ganglions inclusive. When the second lumbar ganglions are removed, the lower extremities are denervated as well. If only the first lumbar ganglions are removed, the effect on the legs varies from practically no inactivation to complete or nearly complete inactivation of sympathetic control. This operation was performed in two stages. The operative mortality was 2.8 per cent. For the present, these variations in extent of operation have been disregarded in the discussion of the effect on blood pressure. Eventually, when the series is larger, the patients will be divided into groups according to the magnitude of operation. Anatomic factors as well as the technic of operation have been previously described.[8] Surgical technic, physiologic effects, complications and mortality will be discussed in greater detail in a future communication.

TABLE 1.—*Effects of Lumbodorsal Splanchnicectomy on the Blood Pressure of One Hundred and Fifty-Six Patients Followed From One to Five Years* *

Result, Group †	No. of Patients	Percentage		Effects of Lumbodorsal Splanchnicectomy: Effect on Diastolic Blood Pressure	Average Reduction
1	64	41.0	61.5	Lowered 30 mm. or more	61/43
2	32	20.5	79.4	Lowered 20 to 29 mm.	44/24
3	28	17.9		Lowered 10 to 19 mm.	27/15
4	17	10.9	20.6	Lowered 0 to 9 mm.	10/ 5
5	15	9.7		Increased (increase)	18/11
Total	156				

* Average time followed, twenty-two and a half months.
† In this table the results are considered as a whole. They have been subdivided into six smaller groups according to type of blood pressure and sex (tables 2, 3 and 4). When subdivided in this fashion, the results are much more helpful in indicating the outlook for the individual patient than when they are undivided, as in this table.

EFFECT OF OPERATION ON BLOOD PRESSURE

The results have been divided into five groups, according to the magnitude of the effect on the horizontal resting diastolic blood pressure level (table 1). In group 1 there was a lowering of 30 mm. or more; in group 2, of 20 to 29 mm.; in group 3, of 10 to 20 mm., and in group 4, up to 10 mm.; in group 5 the blood pressure was higher. The average reduction for the first four groups was 61/43, 44/24, 27/15 and 10/5 mm. respectively. In group 5 the average elevation was 18/11 mm. The results for 61.5 per cent of the patients fell into groups 1 and 2, those for 79.4 per cent, into groups 1, 2 and 3 and those for 20.6 per cent into groups 4 and 5. The results of groups 1 and 2 are regarded as significant and of group 3 as probably significant. The 156 patients have been followed an average of twenty-two and one-half months. Two thirds of the patients have been followed an average of seventeen months and one third an average of thirty-five months. There is no important difference in the results in these two groups of patients. A further period of observation is needed to determine the duration of the effect of operation. White and associates[9] judged the effect of operation by comparing the blood pressure before and after operation for 100 of the patients included in this series. The results were similar to those in this study. The purpose of their analysis was to contrast the effect of lumbodorsal splanchnicectomy with that of nonspecific operations on the blood pressure of hypertensive patients; there was a great difference in favor of splanchnicectomy.

METHOD OF STUDY

The effect of operation has been judged by the change in the horizontal resting diastolic blood pressure. In evaluating the blood pressure of hypertensive patients one must take into consideration the marked variability which is characteristic of hypertension in man. In judging the effect of any form of treatment observations should be made under comparable conditions. Lower levels of blood pressure occur when patients are at rest and higher levels when patients are up and about, subjected to the trials and tribulations and the stresses and strains of life. It is surprising at times to find the resting levels within the normal range, when the levels which are determined in the office or clinic are high. This occasionally may be the case for patients with advanced retinal changes, electrocardiographic changes and severe degrees of arteriolar disease, as judged by renal biopsy, especially in the earlier stages of the disorder, before vascular damage of consequence is evident. Thus, the so-called transient or nervous hypertension may be an extremely important condition.

The resting level is determined by hospitalizing the patient, as a rule for several days, but occasionally for weeks or months, most of which time is spent in bed. Scattered readings of the blood pressure obtained by different nurses are recorded, as well as the readings taken by a physician on the patient's admission to the hospital. Previous readings taken by the patient's physician

8. White, J. C., and Smithwick, R. H.: The Autonomic Nervous System, New York, The Macmillan Company, 1941, p. 469. Smithwick.[3]

9. Rojas, F.; Smithwick, R. H., and White, P. D.: Nonspecific Major Operations and Lumbodorsal Sympathectomy: A Comparision Between Their Effects on the Blood Pressure J. A. M. A. **126**:15-17 (Sept. 2) 1944.

or at the clinic are available for comparison. At the end of this period a more detailed study of blood pressure is performed by the same trained technician, as I have found that lower levels are obtained in this manner than when readings are taken by different nurses or physicians.

The purpose of such a study is to obtain data for the eventual discussion of factors which affect the tone and the reactivity of smooth muscle and for the immediate discussion of the effect of operation on resting levels and on higher levels resulting from stimulation of the patient. Cognizance has been taken of the writings of Hines and Brown[10] in particular, who have among other things demonstrated clearly that the unusual variability of blood pressure in these patients is due to hyperreactivity of the vascular bed to stimuli of one sort or another, particularly cold. When the vascular bed is stimulated with the patient in the resting horizontal position, sharp reflex responses can be demonstrated in the majority of hypertensive patients. The

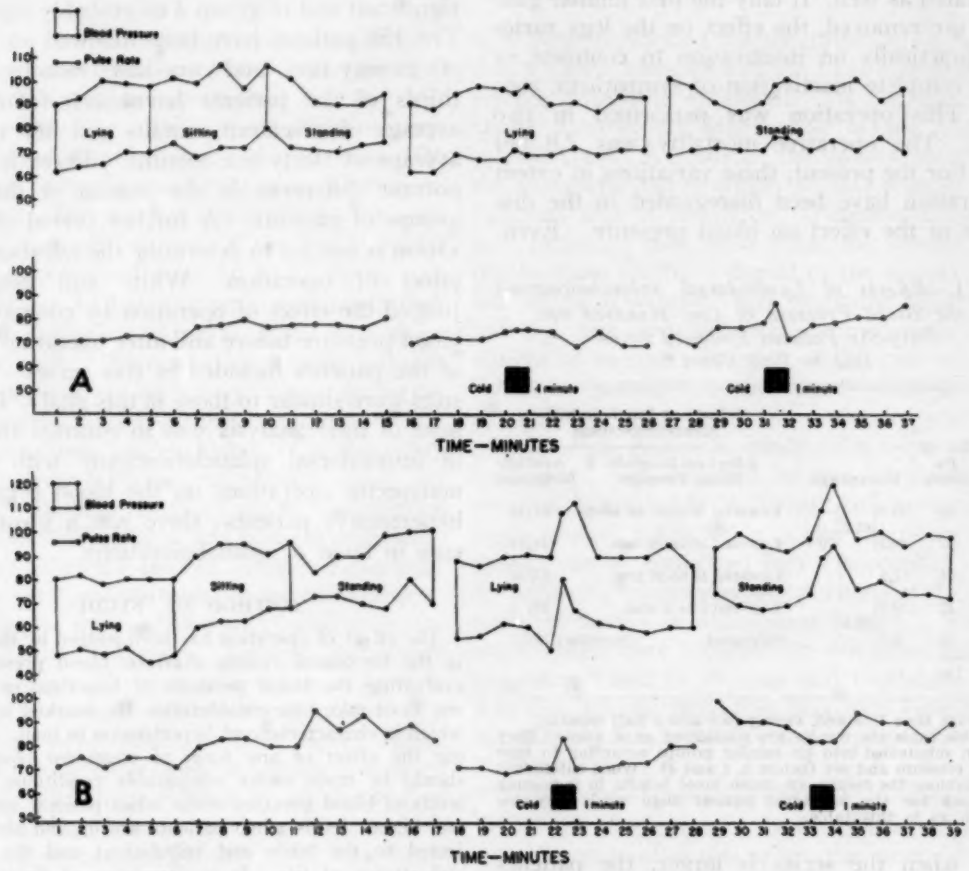

Fig. 1.—*A*, the reaction of a normal subject to the postural and cold test. In the central portion of the test, the reflex response to cold is determined with the subject in the horizontal position. In this patient there was essentially no response. This subject is a hyporeactor, according to the criteria of Hines and Brown, as the response is indicated by a rise in blood pressure of less than 20 mm. systolic and 15 mm. diastolic. They found this to be the case in about 85 per cent of normal subjects. *B*, the reaction of a normal subject to the postural and cold test. This subject is a hyperreactor to cold when stimulated in the horizontal position. According to Hines and Brown, about 15 per cent of normal subjects react in a similar fashion, the response being a rise of more than 20 mm. systolic and 15 mm. diastolic. They also found that about 95 per cent of hypertensive patients react in this abnormal fashion. Note also the unusually active reflex responses of this person to change of posture and to a cold stimulus when standing (compare with *A*).

10. Hines, E. A., Jr., and Brown, G. E.: A Standard Stimulus for Measuring Vasomotor Reactions: Its Application in the Study of Hypertension, Proc. Staff Meet., Mayo Clin. **7**:332-335, 1932; A Standard Test for Measuring the Variability of Blood Pressure: Its Significance as an Index of the Prehypertensive State, Ann. Int. Med. **7**:209-217, 1933. Hines, E. A., Jr.: Reaction of the Blood Pressure of 400 School Children to a Standard Stimulus, J. A. M. A. **108**:1249-1250 (April 10) 1937; The Heredity Factor in Essential Hypertension, Ann. Int. Med. **11**:593-601, 1937; The Significance of Vascular Hyperreaction as Measured by the Cold Pressor Test, Am. Heart J. **19**:408-416, 1940; Range of Normal Blood Pressure and Subsequent Development of Hypertension, J. A. M. A. **115**:271-274 (July 27) 1940; The Background and Treatment of Hypertensive Disease, South. Med. & Surg. **103**:301-306, 1941.

reaction of normal persons to stimulation varies from almost none (fig. 1 *A*) to a marked reaction (fig. 1 *B*), in which the reflex responses are similar to and of the same magnitude as those commonly noted in hypertensive patients.

The test (figs. 1 to 8) is a modification of the Hines-Brown cold stimulation test, in which the latter, performed with the patient in the resting horizontal position, is preceded by a simple postural blood pressure test and followed by a repetition of the cold test with the patient in the upright position. Briefly, after several days or more of hospitalization the patient is taken to a quiet pleasant room and placed on a comfortable bed. After a rest period of fifteen to twenty minutes, readings of blood pressure and pulse rate are taken every minute for five minutes, the patient first lying, then sitting and then standing. The patient then assumes the horizontal position, and readings are continued at one minute intervals for five minutes, followed by stimulation by cold for one minute. The opposite hand is immersed in ice water (4 or 5 C.), and readings are taken after thirty seconds and again in one minute, when the hand is removed. Subsequently, readings are continued every minute for five minutes. The cold test is then repeated with the patient in the upright position.

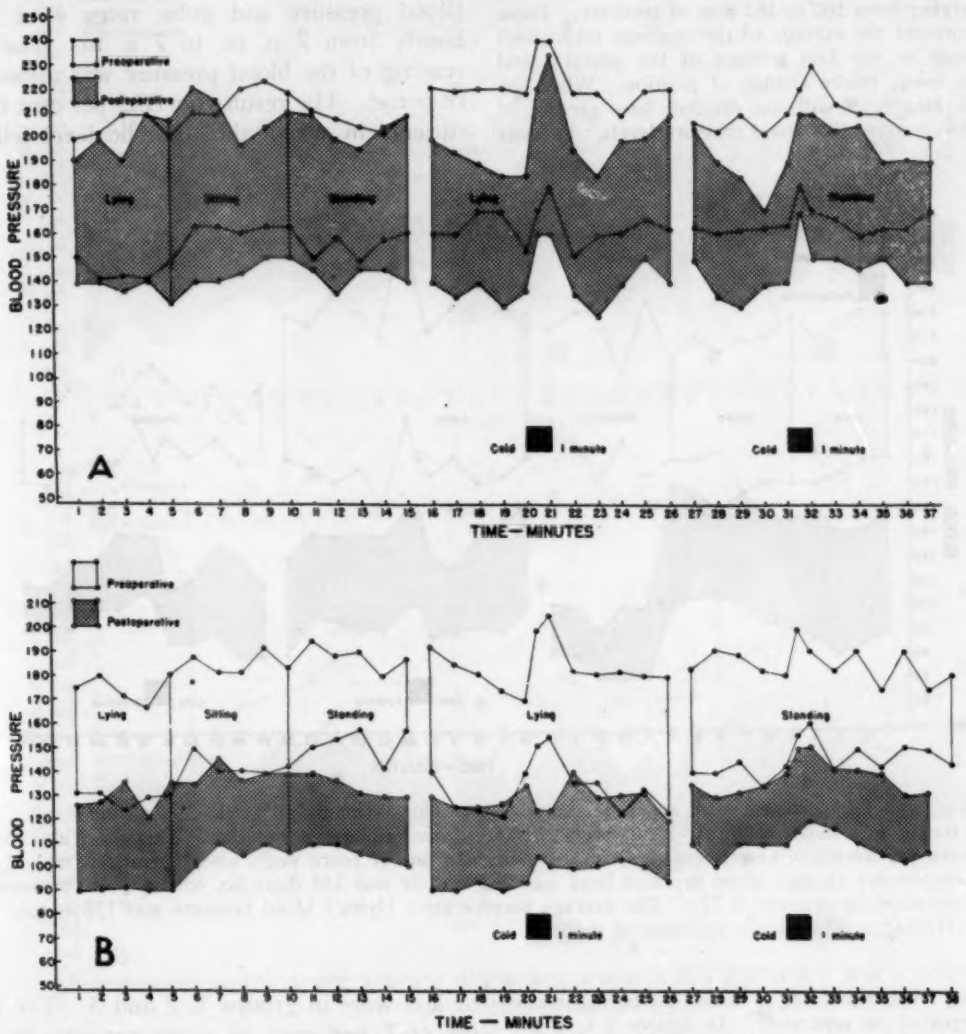

Fig. 2.—Type I hypertension. *A*, a group 4 results. A 30 year old man had grade 4 eyegrounds, early congestive heart failure, poor renal function, a normal nonprotein nitrogen value and a poor response to sedation (table 2). The average preoperative (lying) blood pressure was 203 systolic and 145 diastolic, with a pulse pressure of 58 (one-half the diastolic pressure is 72). The average postoperative (lying) blood pressure was 198 systolic and 136 diastolic. He had a renal biopsy specimen of grade 3. Group 4 and 5 results may occur in patients with grade 0 renal biopsy specimens. *B*, a group 1 result. A 36 year old man had grade 4 eyegrounds, good cardiac and renal functions and excellent response to sedation (table 2). The average preoperative (lying) blood pressure was 175 systolic and 128 diastolic, with a pulse pressure of 53 (one-half the diastolic pressure is 72). The average postoperative (lying) blood pressure was 127 systolic and 90 diastolic. He had a renal biopsy specimen of grade 4.

When they are charted, these data give a graphic picture of the approximate nature and magnitude of the hypertensive state of the particular patient. An opportunity exists to compare the effect of operation on the resting horizontal levels as well as on the higher levels resulting from stimulation by change of position or by cold and on the levels noted prior to hospitalization. The 156 patients included in this report had preoperative horizontal resting diastolic blood pressure levels varying from 100 to 162 mm. of mercury. These levels represent the average of the readings taken with the patients in the first posture of the postural and cold test, lying, before change of position. When the series is larger it will be divided into groups of comparable preoperative blood pressure levels. Patients with resting levels below 100 or within the normal range will be reported on separately. In figures 1 to 8 the readings taken before and after operation are compared, the postoperative chart being cross hatched. The data were obtained in the same fashion except that after operation the patients were ambulatory because of a shortage of beds; consequently they could not be hospitalized for several days before taking the test.

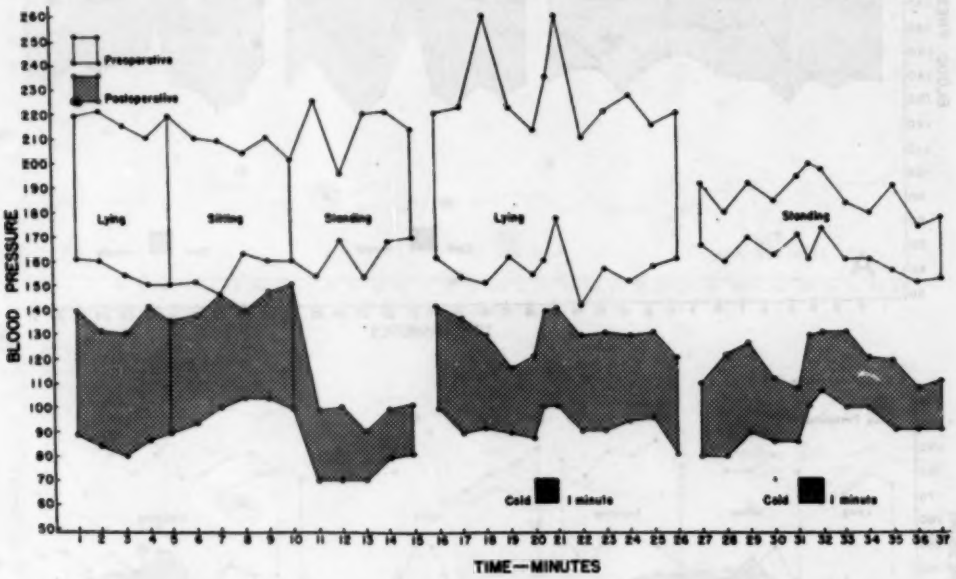

Fig. 3.—Type I hypertension. A group 1 result. A 38 year old man had grade 3 eyegrounds, good cardiac and renal functions, a minor cerebral vascular accident and a fair response to sedation. This chart also illustrates the occasional persistence of asymptomatic postural hypotension one or more years after operation (table 2). The average preoperative (lying) blood pressure level was 217 systolic and 154 diastolic, with a pulse pressure of 63 (one-half the diastolic pressure is 77). The average postoperative (lying) blood pressure was 135 systolic and 85 diastolic. He had a renal biopsy specimen of grade 3.

FACTORS INFLUENCING RESULTS

It is clear that the effect of operation varies considerably, from no change to a distinct lowering of blood pressure. It therefore is extremely important to determine the circumstances under which the better results may be expected. If one reviews the results with reference to each of many factors, all seem to have some importance, but no single one appears to be all important. The duration of hypertension is difficult to evaluate, because it is rarely accurately dated. The age of the patient, the height of the blood pressure and the response to sedation are all factors to be considered. The response to sedation was determined by administering 3 grains (0.19 Gm.) of sodium amytal by mouth at 7, 8 and 9 p. m. Blood pressure and pulse rates were charted hourly from 7 p. m. to 7 a. m. The lowest reading of the blood pressure was taken as the response. The results for 88.5 per cent of those patients in whom the diastolic level fell to 90 or less were in groups 1, 2 and 3. The results for 66.7 per cent of those patients in whom the lowest diastolic level was more than 90 were included in groups 1, 2 and 3. This represents a variation of approximately plus or minus 10 per cent from the percentage of patients (79.4) (table 1) whose results without regard to any particular factor fell into groups 1, 2 and 3. The state of the eyegrounds is of importance. The results for 88.5 per cent of the patients with grade 1 eyegrounds, for 77.2 per cent with grade 2, for 69.1 per cent with grade 3 and for 83.3 per cent with grade 4 were classified in groups 1, 2 and 3. Sex is of importance. Women had better results than men. Results for 71.8 per cent of the men and for 84.8 per cent of the women fell into groups 1, 2 and 3.

TYPES OF HYPERTENSION

A study of the postural and cold test charts has revealed certain important differences in the nature of the hypertensive state, particularly the type of hypertension. This has been judged by the width of the pulse pressure with the patient in the resting horizontal position. The patients have been divided into three classes on this basis. Patients with narrow pulse pressures, which are less than one-half the diastolic pressure, have type I hypertension (figs. 2, 3, 4 and 8). Those with wider pulse pressures, equal to or up to 19 mm. more than one-half the diastolic pressure, have type II hypertension (fig. 5). Those with the widest pulse pressures, 20 mm. or more greater than one-half the diastolic pressure, have type III hypertension (figs. 6 and 7). The result of operation varied with the type, being best for type I and poorest for type III. Eighty-six and five-tenths per cent of the patients with type I, 76.5 per cent with type II and 71 per cent with type III obtained results which were classified in groups 1, 2 and 3.

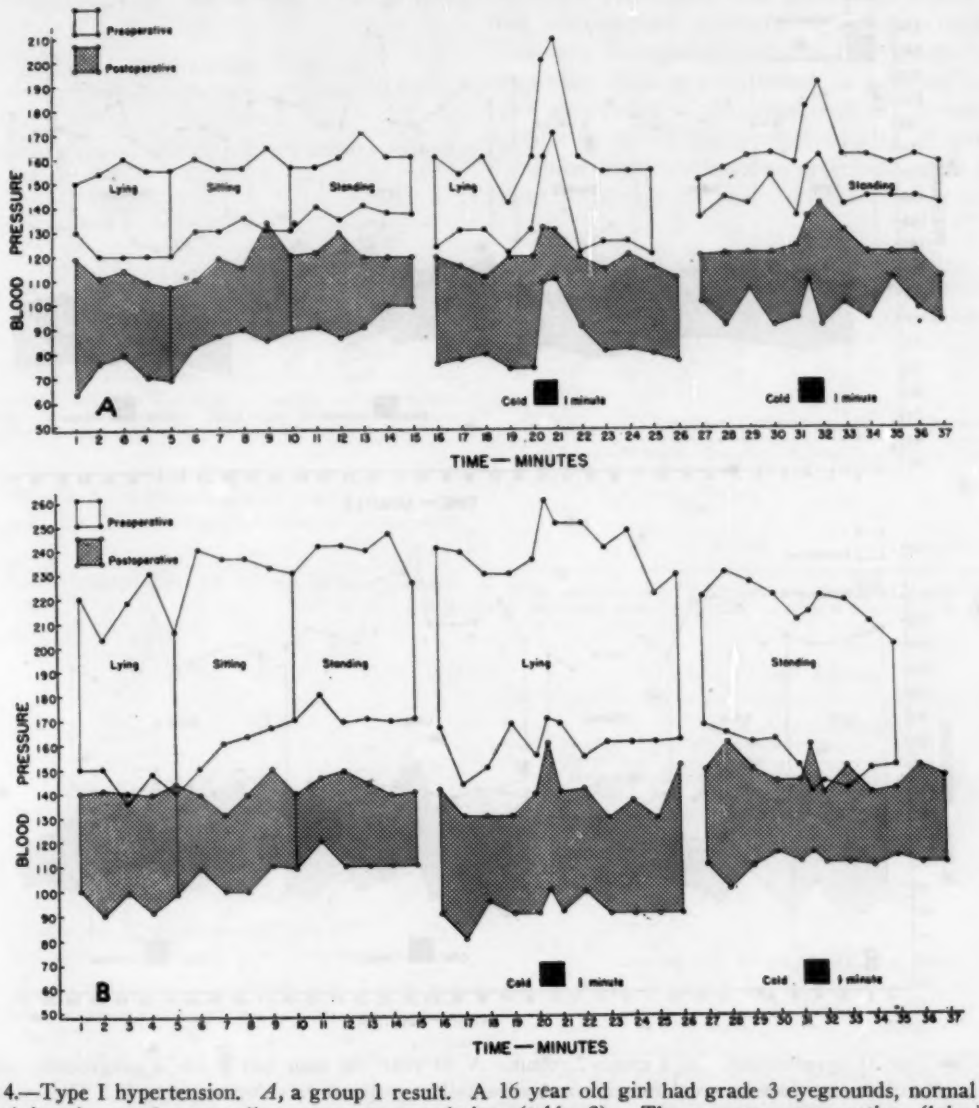

Fig. 4.—Type I hypertension. *A*, a group 1 result. A 16 year old girl had grade 3 eyegrounds, normal cardiac and renal functions and an excellent response to sedation (table 2). The average preoperative (lying) blood pressure was 154 systolic and 122 diastolic, with a pulse pressure of 32 (one-half the diastolic pressure is 61). The average postoperative (lying) blood pressure was 112 systolic and 71 diastolic. She had a renal biopsy specimen of grade 1. *B*, a group 1 result. A 40 year old woman had grade 3 eyegrounds, well marked congestive heart failure, slight impairment of renal function and an excellent response to sedation (table 2). The average preoperative (lying) blood pressure was 215 systolic and 145 diastolic, with a pulse pressure of 70 (one-half the diastolic pressure is 72). The average postoperative (lying) blood pressure was 140 systolic and 95 diastolic. She had a renal biopsy specimen of grade 3.

RESULTS SUBDIVIDED ACCORDING TO TYPE AND SEX

The results have been divided into six groups according to the three types and the two sexes (tables 2, 3 and 4). This necessarily divides such a small series into groups which are not statistically significant. However, such a division seems to cast light on the outlook for the individual patient. When the series becomes larger, the effect of other factors can be taken into consideration. Clinical examples of the three different types of hypertension, the five different groups of results in the two sexes, all grades of changes in the eyegrounds and renal biopsy grades are illustrated in figures 2 to 7. The postoperative charts were made one to two years after the operation. The best results occurred in women with type I and the poorest in men with type III.

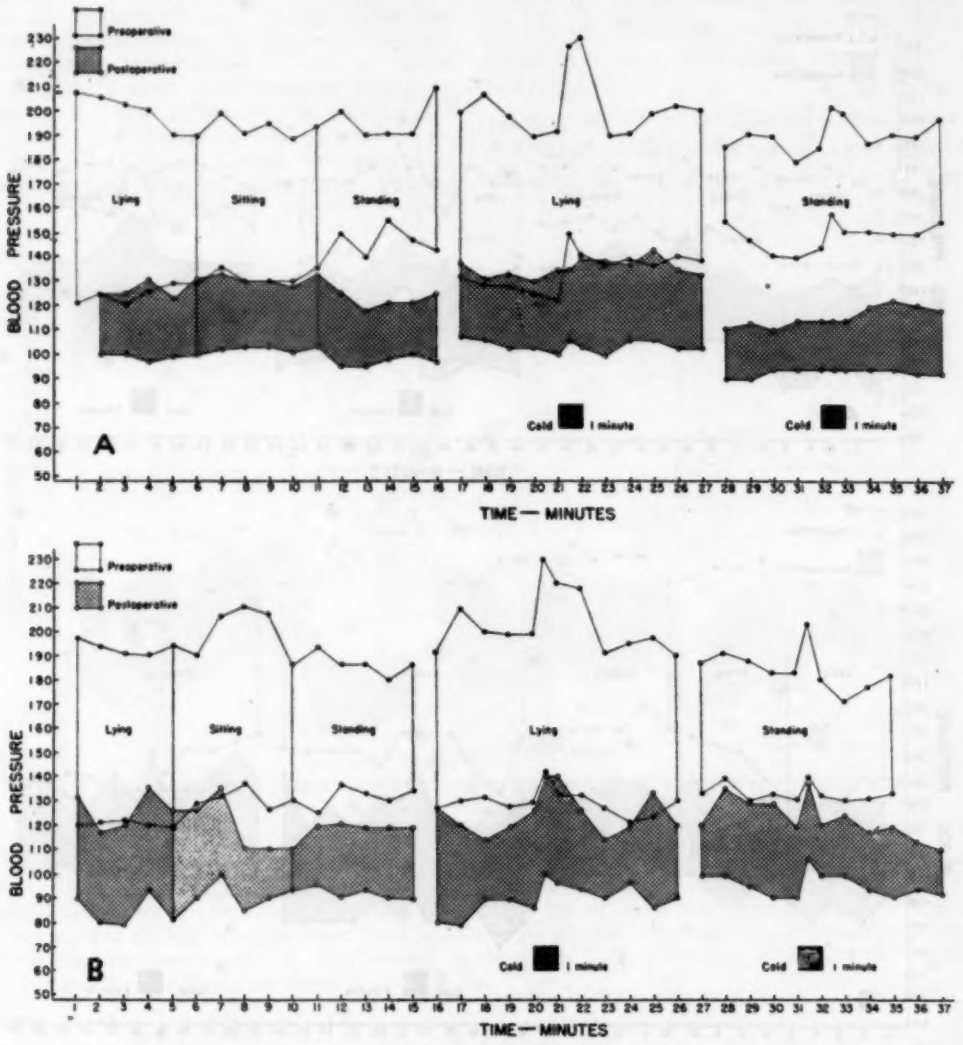

Fig. 5.—Type II hypertension. *A*, a group 2 result. A 50 year old man had grade 4 eyegrounds, mild congestive heart failure, satisfactory renal function and an excellent response to sedation (table 3). The average preoperative (lying) blood pressure was 200 systolic and 125 diastolic, with a pulse pressure of 75 (one-half the diastolic pressure is 62). The average postoperative (lying) blood pressure was 128 systolic and 99 diastolic. He had a renal biopsy specimen of grade 2. *B*, a group 1 result. A 39 year old woman had a severe cerebral vascular accident with partial recovery of function, grade 2 eyegrounds and good cardiac and renal functions, with a good response to sedation. Six and one-half years prior to a lumbodorsal splanchnicectomy she had undergone a laminectomy with extensive section of the anterior roots, without relief of her hypertension (table 3). The average preoperative (lying) blood pressure was 190 systolic and 120 diastolic, with a pulse pressure of 70 (one-half the diastolic pressure is 60). The average postoperative (lying) blood pressure was 125 systolic and 84 diastolic. She had a renal biopsy specimen of grade 3.

PYELONEPHRITIS

Eleven of the 156 patients had chronic pyelonephritis. In all but 1 the disorder was bilateral. As indicated in table 5, women predominated, 9 to 2. All types of hypertension were represented, but type I predominated. All grades of changes in the eyeground occurred. As a group these patients did unusually well. The results of 90.1 per cent of these patients fell into groups 1 and 2, and the results of 100 per cent fell into groups 1, 2 and 3. A clinical example is illustrated in figure 8.

TABLE 2.—*Hypertension—Type I*

	No. of Patients	Result: Group 1	Group 2	Group 3	Group 4	Group 5
Men	34	16	5	5	3	5
		61.7%				
		76.5%			23.5%	
Women	33	20	7	5	0	1
		81.8%				
		96.8%			3.2%	

These patients had type I (the most narrow pulse pressure) hypertension, the pulse pressure being less than one half the diastolic pressure. See figures 2, 3, 4 and 8.

TABLE 3.—*Hypertension—Type II*

	No. of Patients	Result: Group 1	Group 2	Group 3	Group 4	Group 5
Men	16	6	2	4	2	2
		50.0%				
		75.0%			25.0%	
Women	35	14	11	2	6	2
		71.4%				
		77.1%			22.9%	

These patients had type II hypertension (a wider pulse pressure), the pulse pressure being equal to or up to 19 mm. more than one half the diastolic pressure. See figure 5.

TABLE 4.—*Hypertension—Type III*

	No. of Patients	Result: Group 1	Group 2	Group 3	Group 4	Group 5
Men	13	1	2	4	4	2
		23.2%				
		53.8%			46.2%	
Women	25	7	5	8	2	3
		47.8%				
		80.0%			20.0%	

These patients had type III (the widest pulse pressure) hypertension, the pulse pressure being 20 mm. or more greater than one half the diastolic pressure. See figures 6 and 7.

RENAL BIOPSIES

In a previous communication Castleman and Smithwick [11] reported that the evidence of arteriolar disease in the kidneys of living hypertensive patients, as judged by biopsy material obtained at operation, was considerably less than that obtained by a study of autopsy material. This was thought to indicate that much of the arteriolar disease discovered at autopsy developed as a result of the hypertension. It was also noted that while the great majority of patients did show some evidence of arteriolar damage, in about 50 per cent it was mild, minimal or absent.

TABLE 5.—*Pyelonephritis*

No. of Patients	Men	Women	Type I	Type II	Type III	Eyegrounds 1	2	3	4
11	2	9	7	2	2	3	4	3	1

	Results of Lumbodorsal Splanchnicectomy: Group 1	Group 2	Group 3	Group 4	Group 5
11	7	3	1	0	0
	90.1%				
	100.0%			0.0%	

This small series of hypertensive patients with pyelonephritis did unusually well. A clinical example is illustrated in figure 8.

TABLE 6.—*Renal Biopsies*

Renal Biopsy Specimen, Grade	Biopsy Specimens Taken	Result of Lumbodorsal Splanchnicectomy: Group 1	Group 2	Group 3	Group 4	Group 5	No. of Patients
0, 1 and 2	79	24 (42.2%)	9 (15.8%)	13 (22.8%)	3 (5.1%)	8 (14.1%)	57
		58.0%					
		80.8%			19.2%		
3 and 4	75	33 (48.0%)	13 (19.1%)	10 (14.7%)	9 (13.2%)	3 (4.4%)	68
		67.7%					
		82.4%			17.6%		

The effect of operation on blood pressure was essentially the same in the patients with the milder forms of renal arteriolar disease as with the more severe degrees.

These data were obtained from a study of the first 100 consecutive patients for whom biopsy was done. The figures for the present, somewhat larger series are essentially the same. The patients have been divided into two groups according to the grade of the renal changes shown by biopsy (table 6). Those with changes of grades 0, 1 and 2 shown by biopsy (no disease,

11. Castleman, B., and Smithwick, R. H.: The Relation of Vascular Disease to the Hypertensive State, Based on a Study of Renal Biopsies from One Hundred Hypertensive Patients, J. A. M. A. **121**:1256-1261 (April 17) 1943.

minimal and mild) have been placed in one group, and those with grades 3 and 4 (more advanced degrees of arteriolar disease) have been placed in the other group. The effect of operation in the two groups has been compared.

In a previous communication, Talbott and associates [12] determined the amount of blood flowing through the kidneys of 20 patients, most of whom have been included in this series, before and at various intervals after operation. They

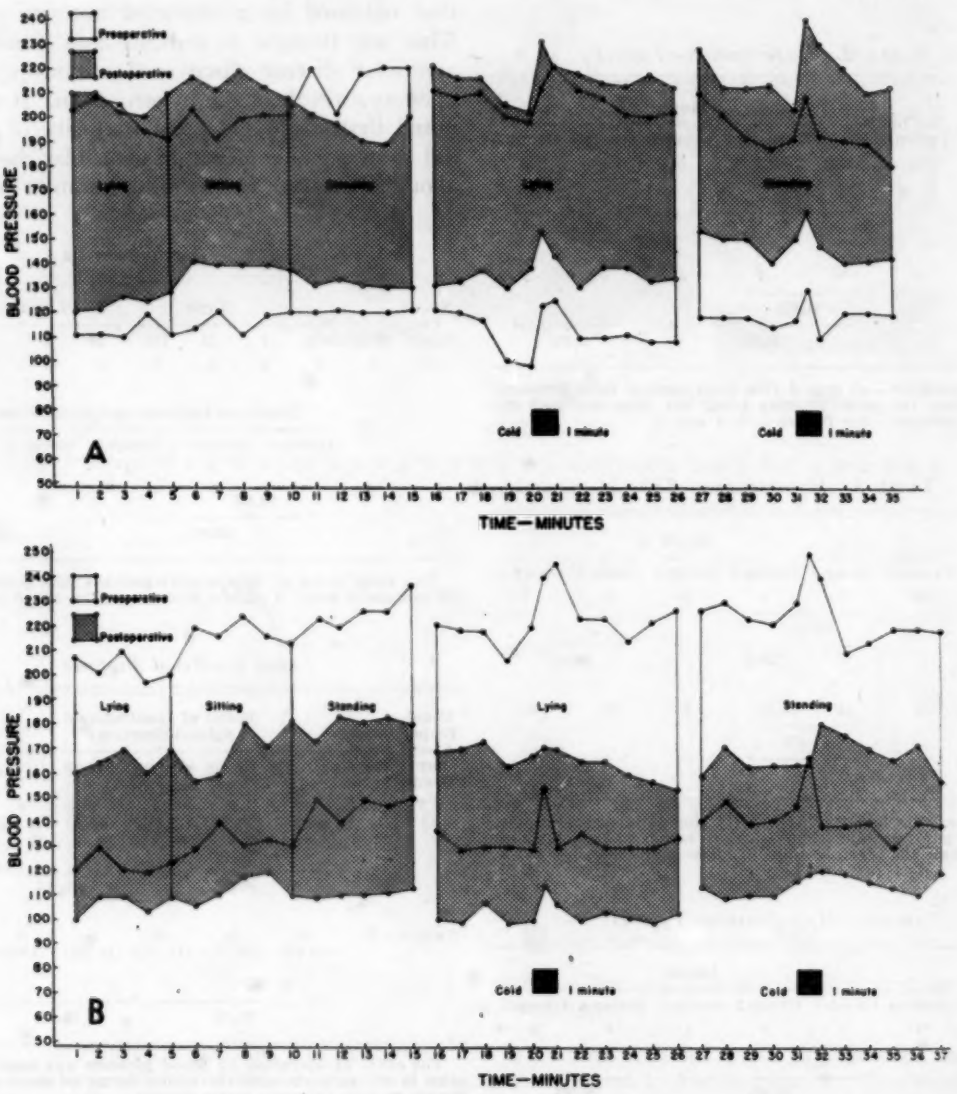

Fig. 6.—Type III hypertension. *A*, a group 5 result. A 48 year old man had grade 3 eyegrounds, impending congestive heart failure, normal renal function and a poor response to sedation (table 4). The average preoperative (lying) blood pressure was 200 systolic and 112 diastolic, with a pulse pressure of 88 (one-half the diastolic pressure is 56). The average postoperative (lying) blood pressure was 207 systolic and 124 diastolic. He had a renal biopsy specimen of grade 2. *B*, a group 3 result. A 45 year old man had grade 4 eyegrounds, well marked congestive heart failure and slight impairment of renal function, with an excellent response to sedation (table 4). The average preoperative (lying) blood pressure was 202 systolic and 121 diastolic, with a pulse pressure of 81 (one-half the diastolic pressure is 60). The average postoperative (lying) blood pressure was 164 systolic and 105 diastolic. He had a renal biopsy specimen of grade 3.

There is essentially no difference, the percentage of patients with different results as regards blood pressure being practically the same for both the milder and the more severe degrees of renal arteriolar disease.

12. Talbott, J. H.; Castleman, B.; Smithwick, R. H.; Melville, R. S., and Pecora, L. J.: Renal Biopsy Studies Correlated with Renal Clearance Observations in Hypertensive Patients Treated by Radical Sympathectomy. J. Clin. Investigation **22**:387-394, 1943.

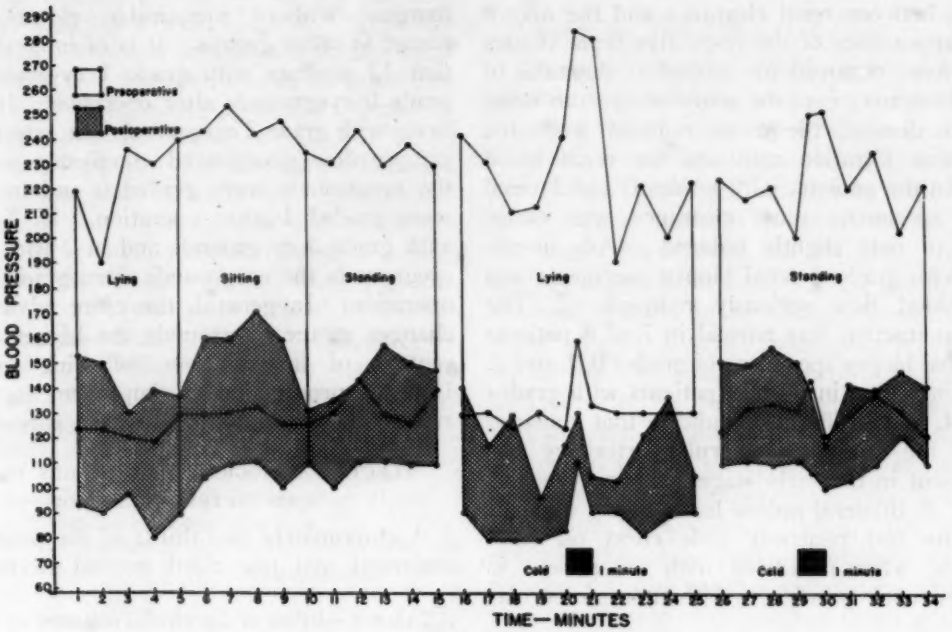

Fig. 7.—Type III hypertension. A group 1 result. A 42 year old woman had grade 3 eyegrounds, satisfactory cardiac and renal functions and a good response to sedation (table 4). The average preoperative (lying) blood pressure was 227 systolic and 123 diastolic with a pulse pressure of 104 (one-half the diastolic pressure is 61). The average postoperative (lying) blood pressure was 141 systolic and 89 diastolic. She had a renal biopsy specimen of grade 0.

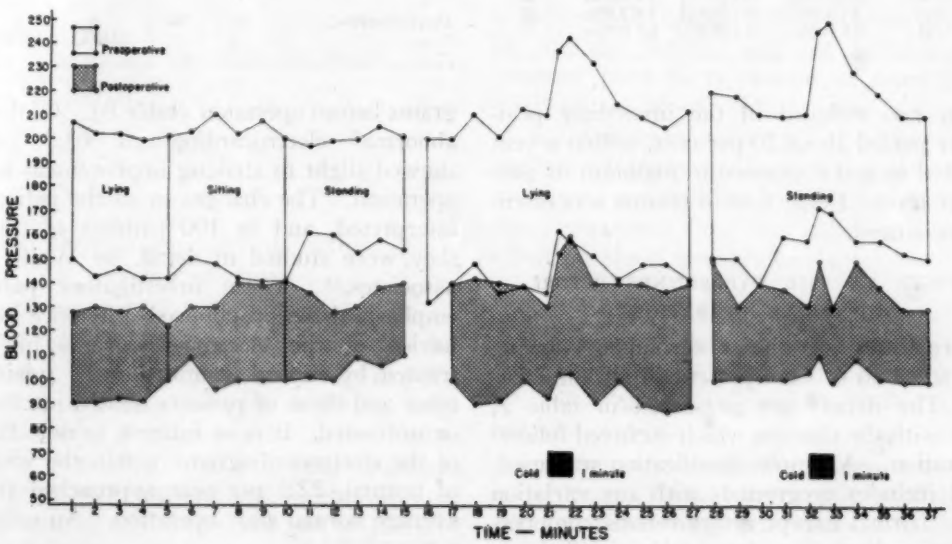

Fig. 8.—Type I hypertension with bilateral chronic pyelonephritis. A group 1 result. A 28 year old woman had grade 4 eyegrounds, moderate reduction of renal function and a fair response to sedation. Two years following operation, this patient had a normal delivery of a normal child. The pregnancy was uneventful, and her hypertension did not recur (table 5). The average preoperative (lying) blood pressure was 202 systolic and 146 diastolic, with a pulse pressure of 56 (one-half the diastolic pressure is 73). The average postoperative (lying) blood pressure was 127 systolic and 93 diastolic. She had a renal biopsy specimen of grade 3.

found: 1. Studies performed on 20 patients with essential hypertension showed a significant correlation between renal clearance and the microscopic appearance of the respective renal tissues which were removed for biopsy at the time of sympathectomy; i. e. the more severe the renal vascular disease, the more reduced were the glomerular filtration rate and the renal blood flow. In the patients with grades 0 and 1 renal biopsy specimens renal clearance was either normal or only slightly reduced. Only in patients with grade 4 renal biopsy specimens was renal blood flow seriously reduced. 2. The filtration fraction was normal in 7 of 8 patients with renal biopsy specimens of grades 0, 1 and 2. It was increased in 6 of 11 patients with grades 3 and 4. These findings indicate that constriction of the efferent glomerular arterioles was not present in the early stages of renal vascular disease. 3. Bilateral radical lumbodorsal splanchnicectomy had relatively little effect on renal clearance, when measured with the patient in the horizontal position. Although glomerular filtration was reduced in the immediate postoperative period about 20 per cent, within a year it returned to and continued to maintain its preoperative level. Renal flow of plasma was essentially unchanged.

TABLE 7.—*Effect of Surgical Treatment of Hypertension on Eyegrounds*

Preoperative Grade of Eyegrounds	No. of Patients Studied	Postoperative			
		Unchanged	Improved	Worse	No. of Patients Followed Up
0	7	5 (83.3%)	.....	1 (16.7%)	6
1	45	22 (56.4%)	13 (33.3%)	4 (10.3%)	39
2	43	10 (31.2%)	19 (59.3%)	3 (9.5%)	32
3	41	8 (21.7%)	28 (75.7%)	1 (2.6%)	37
4	18	0 (0.0%)	15 (100.0%)	0 (0.0%)	15

CHANGES IN THE EYEGROUNDS BEFORE AND AFTER OPERATION

Abnormalities of the eyegrounds, varying from grade 1 to 4, were present in all but 7 patients. The details are presented in table 7, together with the changes which occurred following operation. A simple classification was used. Grade 1 includes eyegrounds with any variation from the normal except arteriovenous compression, hemorrhage, exudate and papilledema. Grade 2 includes eyegrounds with arteriovenous compression but without hemorrhage, exudate or papilledema. Grade 3 includes eyegrounds with hemorrhage or exudate or both but without papilledema. Grade 4 includes all eyegrounds with papilledema and measurable elevation of the disks. These generally exhibited hemorrhage and exudate as well as all types of vascular changes. Many eyegrounds with blurred disk margins without measurable elevation were placed in other groups. It is of interest to note that 13 patients with grade 1 eyegrounds had grade 0 eyegrounds after operation. In 19 patients with grade 2 eyegrounds, the arteriovenous compression disappeared completely and in 8 the eyegrounds were graded 0 and in 11 they were graded 1 after operation. In 7 patients with grade 3 eyegrounds and in 2 with grade 4 eyegrounds the eyegrounds were graded 0 after operation. In general, the more advanced the changes in the eyegrounds the higher the percentage of improvement following operation. Lack of progression or improvement was the rule in the great majority of the patients.

ELECTROCARDIOGRAPHIC CHANGES BEFORE AND AFTER OPERATION

Approximately two thirds of the patients had abnormal and one third normal electrocardiograms before operation (table 8). Of those with abnormal electrocardiograms 63.5 per cent showed slight to striking improvement following operation. The changes in all the patients were interpreted, and in 100 patients of this series they were studied in detail, by White and his associates.[13] These investigators particularly emphasized the pronounced difference in the behavior of the electrocardiograms of patients treated by radical (lumbodorsal) splanchnicectomy and those of patients treated in other ways or untreated. It is of interest to note that even of the electrocardiograms within the wide range of normal, 22.2 per cent approached the more average normal after operation. An unfavorable

TABLE 8.—*Effect of Surgical Treatment of Hypertension on Electrocardiograms*

Preoperative	No. of Patients Studied	Postoperative			
		No. of Patients Followed Up	Unchanged	Improved	Worse
Within normal limits	52	45	34 (76.3%)	10 (22.2%)	1 (1.5%)
Abnormal.....	90	82	25 (30.6%)	52 (63.5%)	5 (5.9%)
Control series.....	50	50	20 (40%)	5 (10%)	25 (50%)

13. Evans, E.; Smithwick, R. H., and White, P. D.: Manifestations of Hypertension Reversible by Adequate Splanchnic Resection, with Special Reference to the Electrocardiogram, to be published. Canabal, E. J.; Warneeford-Thomson, H. F., and White, P. D.: Electrocardiograms of Hypertensive Patients Followed for a Long Time Without Splanchnic Resection in Comparison with Those Who Had Had Splanchnic Resection, to be published.

change was noted in 1.5 per cent of those with normal electrocardiograms and in 5.9 per cent of those with abnormal records. Generally speaking, the evidence indicates lack of downhill progression or improvement in the great majority of patients following operation. Unfavorable progression was noted in half (25 of 50 patients, or 50 per cent) of the control patients, treated in other ways or untreated. Spontaneous improvement was slight at most and rarely observed in the control patients. Patients having the poorest results as regards blood pressure (groups 4 and 5) who were treated by lumbodorsal splanchnicectomy showed a higher percentage of improvement (55.9 per cent) than the control patients (10 per cent) when judged by electrocardiographic changes.

TABLE 9.—*Effect of Surgical Treatment of Hypertension on Renal Function*

		Postoperative			
Preoperative	No. of Patients Studied	Unchanged	Improved	Worse	No. of Patients Followed Up
Albumin 0	48	25 (86.3%)	..	4 (13.7%)	29
Albumin +	90	18 (30.9%)	40 (69.1%)	0	58
Sediment 0	57	27 (96.4%)	..	1 (3.6%)	28
Sediment +	77	17 (34.8%)	32 (65.2%)	0	49
I. V. (normal)	93	74 (98.8%)	..	1 (1.2%)	75
P. S. P. (reduced)	41	6 (18.1%)	26 (78.6%)	1 (3.3%)	33
Urine concentration					
Normal	91	35 (94.7%)	..	2 (5.3%)	37
Reduced	42	2 (10.0%)	18 (90.0%)	0	20

CHANGES IN RENAL FUNCTION BEFORE AND AFTER OPERATION

The majority of patients had persistent albuminuria and changes in the urinary sediment (table 9). On the other hand, the majority had the ability to concentrate urine to 1.020 or more after withholding fluids for twelve hours. Also, the majority had the capacity to excrete 25 per cent or more of phenolsulfonphthalein, injected intravenously, in fifteen minutes and 55 per cent or more in two hours. None of the patients in this series had persistent evidence of retention of nitrogen, although a few were on the borderline. Disappearance of albuminuria, change to normal in the urinary sediment and improvement in ability to concentrate the urine or ability to excrete the dye were noted in the great majority of patients. An unfavorable change in any of these functions was extremely rare.

COMMENT ON THE RESULTS OF GROUPS 4 AND 5

Favorable changes which were noticed in patients with results in groups 4 and 5 including improved eyegrounds for 48.2 per cent of the patients, improved electrocardiograms for 55.9 per cent and improved renal function for 44.4 per cent, suggest that the progress of the disease may have been arrested and the general condition slightly improved in some of these patients. The necessity of studying the blood pressure after operation with the patients ambulatory and comparing it with the blood pressure of resting hospitalized patients before operation may explain, in part at least, the discrepancy between the result as judged by the effect on blood pressure and as judged in these other ways. As Ayman and Goldshine have clearly shown,[7] the effect of operation on blood pressure when it was determinded with the patients ambulatory and judged by a comparison with readings taken at the clinic or office was not significant in certain patients. On the other hand, in these same patients there was a definite lowering of blood pressure following operation, when judged by the blood pressure readings taken at home by the patient or a friend or relative. When favorable changes in the eyegrounds, electrocardiograms, size of the heart or renal function occur after operation, it presumably means that the stress and strain on the vascular bed and the heart have been lessened, most likely because of some favorable effect on the blood pressure, even if the method of study fails to reveal it. I believe that the method of study used in this series tends to understate rather than overstate the results of operation when they are judged solely by the effect on blood pressure levels.

SUMMARY

It is apparent that the blood pressure of many hypertensive patients can be significantly lowered by radical surgical intervention on the autonomic nervous system.

In some patients the reflex responses to stimuli were lessened and occasionally abolished. In many patients, however, even when the levels were generally lower, active reflex responses persisted. When the blood pressure is lowered the pulse pressure may decrease, particularly in patients with wider preoperative pulse pressures. A widening of the pulse pressure after operation is unusual.

The results have been judged by the magnitude of the lowering of the diastolic pressure

and on this basis have been divided into five groups.

These results have been further analyzed by dividing them into three types according to the width of the pulse pressure and tabulating them according to sex. Such a subdivision has been helpful in indicating the circumstances under which better results may be expected.

Favorable changes in eyegrounds, electrocardiograms and renal function, together with an improvement in the well-being of the patients, suggest that lowering of blood pressure is not harmful.

The response of patients with pyelonephritis and hypertension to this form of treatment was unusually satisfactory.

There was no significant difference in the results in patients with mild or no renal arteriolar disease as compared with those in patients with more advanced changes.

The effect of operation on blood pressure does not appear to be primarily dependent on the state of the renal arterioles, as judged by biopsy material, or on known renal disease, such as pyelonephritis, when present.

The results strongly suggest that the state of the extrarenal portion of the visceral vascular bed is important and that the lowering of blood pressure following operation may be largely the result of decreased peripheral resistance to blood flow through this area.

Further observation is needed to determine the duration of the effect. One third of these patients have been followed an average of approximately three years and compare favorably with the others, who have been followed approximately one and one-half years. The patients in the series who were treated first are now entering their sixth postoperative year.

It is reasonable to believe that when the series becomes larger it will be possible to take into consideration other factors, so that the outlook for the individual patient who follows this form of treatment can be predicted with greater accuracy.

ABSTRACT OF DISCUSSION

Dr. E. A. Hines Jr., Rochester, Minn.: Dr. Smithwick's data indicate that extensive sympathectomy may profoundly lower the blood pressure in some patients who are suffering from severe degrees of hypertensive disease. This lowering of the blood pressure may persist for months or even years. It is not evident yet, as Dr. Smithwick has stated, whether a more extensive sympathectomy produces a more permanent result than a less extensive operation. For those who believe that sympathectomy has a place in the treatment of hypertension—and I am one of them—one of the vexing problems has been the accurate identification of those patients who will obtain a good result. The present methods of study of reactions and responses of blood pressure have not answered this adequately. Dr. Smithwick has presented another measuring stick, the range of the pulse pressure, and it is hoped that this will add considerably to the knowledge necessary for selecting the patients with hypertension who should be operated on.

Dr. Geza de Takats, Chicago: Dr. Smithwick has been modest about describing the various difficulties in the technic of splanchnic section. He has finally evolved a type of operation which has been eminently successful. It was necessary for him to try out a number of less extensive splanchnic sections before he arrived at his present method, and ever since he published this method I have followed his technic, since the previous methods did not give such satisfactory results. In his present paper he has presented the second phase of the problem. He has also emphasized that there probably will never be a single test or a single criterion for indicating the advisability of operation. It will be necessary to take into consideration a number of factors. In my own work I have roughly recognized three groups which come for operation. One group of patients have the early juvenile type of hypertension with minimal or no detectable organic changes and with complete response to sedation; for this group I feel that radical sympathectomy has offered during the period of observation, which now goes back five or six years, excellent results.

There is another group for whom I feel that splanchnic section is not indicated. These patients are in the late stage of the disease: the malignant phase or the late benign phase of hypertension with rigid major arteries. This condition is best expressed by the index that Dr. Smithwick has just shown, the large pulse pressure. There is, however, the intermediate group of patients, with a mixture of organic and functional pathologic conditions. I have had my best results with the posteclamptic or post-toxemic type of hypertension in women who obviously had organic vascular disease. I have also seen good results with the latent nephritic type of hypertension; however, this type has been recognized only after renal biopsy, since clinically it belongs to the essential type.

The mechanism of relief which is obtained with section of the splanchnic nerve should be studied in the future. It is generally agreed now that there is no detectable change in renal function, that the release of splanchnic vasoconstriction is an important point and that adrenal denervation should not be forgotten. It should also not be forgotten that there are various vascular depots in the splanchnic area, as in the liver and the spleen, which do not function as depots after splanchnic section. There are many factors involved which are not understood and which the physiologist has not cleared up. Until an effective drug or diet is found splanchnicectomies will have to be done in well selected cases.

Dr. N. S. Davis, Chicago: Sympathectomy paralyzes the renal arterioles and prevents the ischemia caused by the hypertension but does not eliminate the causes of the altered renal cellular chemistry, deamination by decarboxylization with the formation of pressor amines. It prevents extension of the process and permits some reversal by limiting the ischemia but does not prevent the development of pathologic cellular anatomy that is caused by the pathologic cellular chemistry. Sympathectomy must therefore be considered a palliative procedure which at times has distressing side effects.

Dr. Roy W. Scott, Cleveland: In 68 cases Dr. Smithwick found severe vascular disease even in the

small section of the kidney removed at operation; this means of course that probably the entire vascular system of the kidney was involved. In 57 cases he found less severe vascular disease, and in 7 per cent of his first 100 cases in which biopsy was made no vascular disease was found. Before concluding, as Smithwick does, that his findings in this smaller group of 57 cases are not in keeping with the concept that renal arterial and arteriolar disease is the cause of human essential hypertension, one must recall the limitations imposed by the study of a biopsy section from a living kidney. At best, not more than 10 preglomerular arterioles can be identified, and since there are about 1,250,000 afferent glomerular arterioles in each kidney, a sample of 1 in 125,000 is obtained. Therefore, failure to see significant vascular changes in the small mass of kidney removed at biopsy can scarcely justify the conclusion that no such lesions exist. Besides, no biopsy of the cortex of the kidney can give any estimate of the condition of the renal artery or its main branches.

Dr. Smithwick has found less arteriolar disease in biopsy material obtained at operation than has been observed by others in autopsy material, and from this he concludes that "much of the arteriolar disease seen at death developed as a result of the hypertension." Since a renal biopsy affords an inadequate sample of the entire kidney, no correlation between biopsy and autopsy material can be made. Furthermore, the average age of his patients treated surgically was 37 years, whereas the average age of hypertensive patients who come to autopsy is much greater.

In assaying the ultimate therapeutic value of surgical operation on patients with vascular disease and hypertension, one must consider the relation of sex to the disease. In Dr. Smithwick's series there were 92 females and 64 males. Is it possible that the recognized vasomotor instability of the female has influenced Dr. Smithwick's favorable therapeutic results?

I agree that further observations are necessary to determine the duration of the beneficial effects of sympathectomy on hypertension. Whether or not the span of life is any longer for patients treated by surgical operation than it is for those treated medically has not been determined. No series of hypertensive patients subjected to operation has been more carefully and critically studied than that reported by Dr. Smithwick.

Dr. Reginald H. Smithwick, Boston: Dr. Scott has raised certain questions regarding the validity of biopsy material, and I think his point is correctly taken. I recognize the questionable value of biopsy material and have commented on it in various communications. When the biopsy specimen showed no evidence of renal vascular disease, of course it was wholly possible and perhaps even probable that serial sections of the kidney would have demonstrated vascular disease in other areas. On the other hand, when biopsy material showed severe arteriolar disease, such as grade 4, which is the most advanced grade and which is as advanced as is seen in autopsy material, then, as Dr. Scott has indicated, the data are probably significant, because it would be unlikely to obtain a renal biopsy specimen of grade 4 (severe arteriolar disease) and another of grade 0 (little or no disease) from another part of the kidney. There seems to be little difference in the effect of operation on blood pressure when the various grades of the renal biopsy specimens are taken into consideration. It is of interest that in the presence of a condition in which biopsy specimens look like autopsy material one can still obtain a striking result from operation; all of this leads one to wonder why the blood pressure is lower and how the lower level can be explained. It seems as though one would have to consider the probability of a decreased peripheral resistance to the flow of blood through some areas other than the kidneys. Such an explanation is further suggested by the favorable effect of operation on patients with primary renal disease, such as pyelonephritis.

PROGRESS IN ORTHOPEDIC SURGERY FOR 1943

A REVIEW PREPARED BY AN EDITORIAL BOARD OF THE AMERICAN ACADEMY OF ORTHOPAEDIC SURGEONS

(Continued from Page 146)

IV. NEUROMUSCULAR DISORDERS EXCLUSIVE OF POLIOMYELITIS

PREPARED BY WINTHROP M. PHELPS, M.D., BALTIMORE

Injuries to Nerves.—In this series of disorders are included injuries in or about the shoulder girdle due to a variety of causes. Hauser and Martin [106] present 2 additional cases of winged scapula occurring in the armed forces; in 1 case the condition resulted from repeated lifting of heavy objects and in the other from an automobile accident. In both there was isolated paralysis of the serratus anterior muscle.

Burnard and Fox [107] present 9 cases of multiple neuritis of the shoulder girdle resulting from various causes which occurred in the second New Zealand Expeditionary Force.

Clausen [108] reviews the literature and reports 9 cases of postoperative or anesthetic paralysis of the brachial plexus.

Ramirez [109] reports several cases of brachial paralysis following the administration of serum.

Saksena [110] reports paralysis of the serratus anterior muscle following glandular fever.

[ED. NOTE.—This series of papers is especially interesting because of the varied causes of similar resultant conditions. The brachial plexus is apparently susceptible to injury, and this may be in part explained by the high degree of mobility of the entire structure of the shoulder girdle and the consequently greater exposure to stretching and other trauma.]

Disease Entities.—Milhorat [111] describes 2 cases of familial progressive muscular atrophy of the peroneal type associated with atrophy of the optic nerve. The peroneal type of muscular atrophy is well known but is not by any means always a familial disease. When it is associated with atrophy of the optic nerve it probably is a different entity, with a different cause, as this interesting presentation suggests.

Swank and Putnam [112] present a clinical analysis of amyotrophic lateral sclerosis and related conditions of muscular atrophy and discuss the differential diagnosis between amyotrophic lateral sclerosis and primary lateral sclerosis and progressive muscular atrophy. The paper deals with the finer points of distinction, as they have a bearing on the treatment and the course of the conditions.

Swank and Price [113] discuss the origin of fascicular muscular twitchings in amyotrophic lateral sclerosis.

Milhorat and Wolff [114] have analyzed on a statistical basis the relationship between the age of onset of symptoms and the clinical course of progressive muscular dystrophy.

Lubin, Marburg and Tamaki [115] bring out the relationship of familial muscular atrophy to other

106. Hauser, C. U., and Martin, W. F.: Two Additional Cases of Traumatic Winged Scapula Occurring in the Armed Forces, J. A. M. A. **121**:667-668 (Feb. 27) 1943.

107. Burnard, E. D., and Fox, T. G.: Multiple Neuritis of Shoulder Girdle: A Report of Nine Cases Occurring in the 2nd New Zealand Expeditionary Force, New Zealand M. J. **41**:243-247 (Dec.) 1942.

108. Clausen, E. G.: Postoperative ("Anesthetic") Paralysis of Brachial Plexus: Review of Literature and Report of Nine Cases, Surgery **12**:933-942 (Dec.) 1942.

109. Ramirez, F.: Parálisis post-séricas, Arch. urug. de med., cir. y especialid. **21**:545-550 (Nov.) 1942.

110. Saksena, H. C.: Paralysis of Serratus Anterior Following Glandular Fever, Brit. M. J. **2**:267 (Aug. 28) 1943.

111. Milhorat, A. T.: Studies in Diseases of Muscle: Progressive Muscular Atrophy of Peroneal Type Associated with Atrophy of Optic Nerve; Report on a Family, Arch. Neurol. & Psychiat. **50**:279-287 (Sept.) 1943.

112. Swank, R. L., and Putnam, T. J.: Amyotrophic Lateral Sclerosis and Related Conditions: Clinical Analysis, Arch. Neurol. & Psychiat. **49**:151-177 (Feb.) 1943.

113. Swank, R. L., and Price, J. C.: Fascicular Muscle Twitchings in Amyotrophic Lateral Sclerosis: Their Origin, Arch. Neurol. & Psychiat. **49**:22-26 (Jan.) 1943.

114. Milhorat, A. T., and Wolff, H. G.: Studies in Diseases of Muscle: Heredity of Progressive Muscular Dystrophy; Relationship Between Age at Onset of Symptoms and Clinical Course, Arch. Neurol. & Psychiat. **49**:641-654 (May) 1943.

115. Lubin, A. J.; Marburg, O., and Tamaki, K.: Familial Type of Paralysis in Infants and Its Relationship to Other Heredofamilial Disorders: Clinicopathologic Study, Arch. Neurol. & Psychiat. **49**:27-42 (Jan.) 1943.

heredofamilial neurologic disorders in a clinicopathologic study.

Homburger [116] points out the changes in the thymus, particularly those associated with myasthenia gravis which he observed in 6,000 autopsies.

Mueller and Sugar [117] have found instances of familial syringomyelia.

[Ed. Note.—All of the preceding papers are interesting from the point of view of analyses of the diseases, clinically and pathologically, and from the point of view of differential diagnosis, but it is also interesting that in the literature for 1943 there are relatively few articles concerning the advancement of therapy. What has been accomplished seems still to be related to the use of neostigmine compounds, atropine derivatives and vitamins. The reports on treatment are discussed later in this section.]

DeJong [118] reports a case of the syndrome of involvement of the posterior cord of the brachial plexus, resulting from a traumatic anterior dislocation of the shoulder, with loss of function in the deltoid and the teres major muscle and the other muscles which are supplied by the axillary nerve and the related nerves comprising the posterior cord of the brachial plexus.

Sahs and Paul [119] describe the differential diagnosis between neuronitis and poliomyelitis and point out the chief distinguishing characteristics of the two diseases. They also show that the use of the "Kenny" treatment did not forestall an increase in the paralysis in the progressive phase of the disease (neuronitis).

Hassin [120] discusses Landry's paralysis and points out that it is not an entity but a symptom complex. He emphasizes that in every case the muscles of respiration and the condition of the heart should be examined carefully, in addition to the usual areas of involvement, because of the relationship of these muscles to the course of the disease.

116. Homburger, F.: Changes in Thymus with Special Reference to Myasthenia Gravis: Observations in Series of Six Thousand Autopsies, Arch. Path. **36**:371-380 (Oct.) 1943.

117. Mueller, C. R., and Sugar, S. J.: Familial Syringomyelia, J. A. M. A. **122**:743-744 (July 10) 1943.

118. DeJong, R. N.: Syndrome of Involvement of Posterior Cord of Brachial Plexus, Arch. Neurol. & Psychiat. **49**:860-862 (June) 1943.

119. Sahs, A. L., and Paul, W. D.: Neuronitis: Differentiation from Poliomyelitis, Arch. Phys. Therapy **24**:395-401 (July) 1943.

120. Hassin, G. B.: Landry's Paralysis: Its Clinical and Pathologic Features, J. Neuropath. & Exper. Neurol. **2**:293-300 (July) 1943.

Cerebral Palsy.—Dynes [121] discusses the prevalence of subacromial bursitis in conjunction with neurologic conditions such as hemiplegia. Bursitis associated with a neurologic condition is not treated any differently than when it occurs independently, but the treatment must be modified by the course of the associated disease.

Norfleet and Arena [122] emphasize the responsibility of the pediatrician to infants with cerebral palsy and the importance of classification of the condition, which can be made as a result of early tests and examinations of infants with suspected birth injury.

Shapiro [123] surveys the literature on aseptic lymphocytic meningitis and discusses the cause, the clinical picture and the pathologic changes. He then presents a case in which this condition is associated with infantile cerebral palsy in the adult form. The differential diagnosis is considered.

Barr [124] describes a procedure for transplantation of a muscle for combined flexion–internal rotation deformity of the thigh in spastic paralysis. This operation is limited to true spastic cerebral birth palsy and does not succeed in athetosis. It consists in freeing the tensor fasciae latae, with the anterior third of the gluteus medius and minimus muscles, from their iliac origins and reattaching them to the ilium at a point slightly posterior to the greater trochanter. Results were satisfactory.

McCarroll and Schwartzmann [125] analyze 1,720 cases of spastic paralysis and allied disorders from the standpoint of classification, characteristics and etiology. In 1,217 cases the pyramidal tract was involved, and these cases were discussed with regard to extremities involved, requirements for surgical correction and reasons for avoiding surgical intervention.

They list the deformities for which surgical intervention is justified in cases of involvement of the pyramidal tract (or spastic) paralysis. They point out also that the presence of athetosis

121. Dynes, J. B.: Subacromial Bursitis Associated with Diseases of Nervous System, Lahey Clin. Bull. **3**:124-127 (April) 1943.

122. Norfleet, G. M., and Arena, J. M.: Cerebral Palsy and the Pediatrician, North Carolina M. J. **4**: 55-58 (Feb.) 1943.

123. Shapiro, L. B.: Aseptic Lymphocytic Meningitis in a Case of Infantile Cerebral Palsy, Adult Form, J. Nerv. & Ment. Dis. **97**:166-169 (Feb.) 1943.

124. Barr, J. S.: Muscle Transplantation for Combined Flexion-Internal Rotation Deformity of Thigh in Spastic Paralysis, Arch. Surg. **46**:605-607 (May) 1943.

125. McCarroll, H. R., and Schwartzmann, J. R.: Spastic Paralysis and Allied Disorders, J. Bone & Joint Surg. **25**:745-767 (Oct.) 1943.

is usually a contraindication to surgical procedures on the extremities.

Deaver and Brown [126] describe the vocational rehabilitation of persons handicapped by cerebral palsy and the results obtained in working with adults with this condition.

St. James [127] describes a new type of skis for training persons with cerebral palsy to walk, which permits a normal reciprocal arm swing in the gait.

Lundeen,[128] Werner [129] and Leone Bloise,[130] in three separate papers, present and discuss different aspects of the general problem of the care and treatment of persons with cerebral palsy.

Surgical Procedure for Neuromotor Conditions.—Stabins and Mathews [131] report neurolysis and transposition of the nerve as the operation of choice in the treatment of traumatic paralysis of the ulnar nerve. Their results with this operation have been superior to those with other methods.

Thomsen, Altamirano and Luco [132] have studied the effects of tenotomy on neuromuscular transmission and present some interesting data, which may have a bearing on other variations in transmission, which have been studied in the laboratory.

Dandy [133] describes a method of restoring the function of nerves which require resection for removal of neuromas. He states that to avoid complications nerves should be resutured end to end at the earliest possible moment compatible with the patient's condition and the condition of the wound. If the patient is not seen until later, however, he advises resection and shortening of the bone by osteotomy, to prevent undue strain on the nerve; the bone should be sufficiently shortened to allow accurate suturing. If a neuroma has to be excised the shortening of the bone should be sufficient to allow suturing without undue tension on the suture line.

The paper of Highet and Sanders [134] and that of Highet and Holmes [135] are of interest in this same connection. The first describes the effects of stretching nerves in general after suturing, and the second, the results of traction injuries to peripheral nerves in particular.

Physical Therapy for Neuromuscular Disorders.—DeJong [136] describes a new instrument, which is a portable electrostimulator, to be used on nerves and muscles, both for diagnostic and for therapeutic purposes. As a diagnostic aid it is valuable, because of its compactness and portability, for determining conditions of a peripheral nerve (injury, inflammation, etc.) and for determining the reaction of degeneration. It is also of value in determining decreased excitability to galvanic current (as in myasthenia). For therapeutic purposes it can be used to stimulate paralyzed muscles in peripheral lesions to prevent atrophy, to supply galvanic current and to introduce substances into tissues (iontophoresis).

Solandt, DeLury and Hunter [137] present the effects of electrical stimulation on atrophy of denervated skeletal muscle. They conclude that electrical stimulation is effective in reducing the loss of weight of denervated muscle; this conclusion bears out those of other workers in this respect.

They found that a 25 cycle sinusoidal current is better than a 60 cycle current but that both are superior to galvanic and faradic currents.

The effectiveness of treatment increases with the number of treatments, but the length of each treatment is much less important.

126. Deaver, G. G., and Brown, M. E.: Making Man Power: Vocational Rehabilitation of Those Handicapped by Cerebral Palsy, Arch. Phys. Therapy **23**: 719-728 (Dec.) 1942.

127. St. James, R.: Reciprocal Action Skis in Treatment of Cerebral Palsy, Physiotherapy Rev. **23**:199-200 (Sept.-Oct.) 1943.

128. Lundeen, P.: Cerebral Palsy or Spastic Paralysis, Physiotherapy Rev. **23**:17-21 (Jan.-Feb.) 1943.

129. Werner, A.: Spastic Paralysis: Problem of Little's Disease, Psychiat.-neurol. Wchnschr. **44**:402 (Dec. 19) 1942.

130. Leone Bloise, N.: Reeducación psico-motriz en niños lisiados y espasmódicos, Arch. de pediat. d. Uruguay **14**:201-208 (April) 1943.

131. Stabins, S. J., and Mathews, W. H.: Traumatic Ulnar Nerve Palsy: Neurolysis and Transposition of Nerve; the Operation of Choice, U. S. Nav. M. Bull. **41**:1381-1388 (Sept.) 1943.

132. Thomsen, P.; Altamirano, M., and Luco, J. V.: Efectos de la tenotomía sobre la transmisión neuromuscular, Medicina, Buenos Aires **3**:67-75 (Oct.) 1942.

133. Dandy, W. E.: Method of Restoring Nerves Requiring Resection, J. A. M. A. **122**:35-36 (May 1) 1943.

134. Highet, W. B., and Sanders, F. K.: Effects of Stretching Nerves After Suture, Brit. J. Surg. **30**: 355-369 (April) 1943.

135. Highet, W. B., and Holmes, W.: Traction Injuries to Lateral Popliteal Nerve and Traction Injuries to Peripheral Nerves After Suture, Brit. J. Surg. **30**: 212-233 (Jan.) 1943.

136. DeJong, H.: New Single-Unit Portable Electrostimulator of Nerves and Muscles, J. Nerv. & Ment. Dis. **97**:563-566 (May) 1943.

137. Solandt, D. Y.; DeLury, D. B., and Hunter, J.: Effect of Electrical Stimulation on Atrophy of Denervated Skeletal Muscle, Arch. Neurol. & Psychiat. **49**:802-807 (June) 1943.

Three papers are recorded dealing with various phases of the treatment of muscles after injury to a nerve. The first, by Hines,[138] discusses the physiologic basis for treatment; the second, by Chamberlain,[139] points out the relation of physical therapy to injuries of the peripheral nerves, and the third, by Dube,[140] discusses physical therapy following suturing of nerves.

Staples and Watkins[141] describe 2 cases in which full active abduction was possible after paralysis of the deltoid muscle. They state that this is possible by the interaction of the supraspinatus, infraspinatus, pectoralis major, coracobrachialis, long head of the biceps, serratus magnus and trapezius muscles. Different groups of these muscles operate to bring about abduction in different positions of internal and external rotation. They advocate careful training and study of cases of isolated paralysis of the deltoid muscle before resorting to surgical operation.

Drug Therapy for Neuromuscular Disorders.—All the reports on therapy deal with three general classes of drugs: vitamin E (alpha tocopherol), atropine (and its derivatives) and neostigmine.

In regard to vitamin E, Houchin and Mattill,[142] in experiments on animals, compare the oxygen consumption, the creatine content and the chloride content of muscles of animals deficient in vitamin E with those of normal animals and report the effect of feeding tocopherol to the deficient animals.

The same authors, in another paper,[143] describe the changes in metabolic processes produced by injection of alpha tocopherol phosphate into dystrophic muscles.

Houchin,[144] in a third paper, shows the in vitro effect of alpha tocopherol phosphate on oxidation in muscle tissue.

Hines, Lazere, Thomson and Cretzmeyer[145] discuss the role of vitamin E in neuromuscular atrophy and regeneration.

Septien[146] records results of the use of vitamin E on muscular atrophy following poliomyelitis.

[ED. NOTE.—The preceding papers suggest that vitamin E plays some part in the metabolism of muscle and that it is of value when there is a vitamin E deficiency in the diet or in conditions in which vitamin E is destroyed by a disease process with resultant E avitaminosis. Work has been carried on in the last few years on all phases of the problem in many laboratories. In the reports of 1942, many of which were clinical, the results of using vitamin E therapeutically were discouraging, but many of the workers are continuing the investigation because of the overwhelming evidence concerning its therapeutic value found in laboratory studies. Advances in the understanding of the effect of lack of vitamin E are still being made; the problem will probably become more and more clarified.]

Soskin and Levine[147] demonstrate that muscular atrophy following section of nerves in monkeys can be inhibited by the use of atropine sulfate; they had previously shown that atropine decreased the degree of atrophy in rats also. They feel that because of this demonstration in monkeys it might be of therapeutic value for human beings.

Fischer[148] also shows the influence of atropine on muscular contractions in denervated skeletal muscles of rats.

Lazere, Thomson and Hines[149] and Solandt, DeLury and Hunter[150] contribute to the sub-

138. Hines, H. M.: Physiologic Basis for Treatment of Paralyzed Muscle, Arch. Phys. Therapy **24**: 69-73 (Feb.) 1943.

139. Chamberlain, R. D.: Some Aspects of Physical Therapy in Relation to Peripheral Nerve Injuries, Arch. Phys. Therapy **24**:603-609 (Oct.) 1943.

140. Dube, P.: Symposium on Military Physical Medicine: Physical Therapy Following Suture of Nerves, M. Clin. North America **27**:1091-1096 (July) 1943.

141. Staples, O. S., and Watkins, A. L.: Full Active Abduction in Traumatic Paralysis of Deltoid, J. Bone & Joint Surg. **25**:85-89 (Jan.) 1943.

142. Houchin, O. B., and Mattill, H. A.: Oxygen Consumption, Creatine, and Chloride Content of Muscles from Vitamin E-Deficient Animals as Influenced by Feeding α-Tocopherol, J. Biol. Chem. **146**:301-307 (Dec.) 1942.

143. Houchin, O. B., and Mattill, H. A.: Influence of Parenteral Administration of α-Tocopherol Phosphate on Metabolic Processes in Dystrophic Muscle, J. Biol. Chem. **146**:309-312 (Dec.) 1942.

144. Houchin, O. B.: In Vitro Effect of α-Tocopherol and Its Phosphate Derivative on Oxidation in Muscle Tissue, J. Biol. Chem. **146**:313-321 (Dec.) 1942.

145. Hines, H. M.; Lazere, B.; Thomson, J. D., and Cretzmeyer, C. H.: Role of Vitamin E in Neuromuscular Atrophy and Regeneration, Am. J. Physiol. **139**: 183-187 (June) 1943.

146. Septien, R.: Vitamin E in Treatment of Muscular Atrophies Following Infantile Paralysis, J. Am. Inst. Homeop. **36**:17-18 (Jan.) 1943.

147. Soskin, S., and Levine, R.: Influence of Atropine on Atrophy of Denervated Skeletal Muscle of Monkey (Macacus Rhesus), Am. J. Physiol. **138**:251-253 (Jan.) 1943.

148. Fischer, E.: Influence of Atropine on Atrophy of Denervated Skeletal Muscle of the Rat, Proc. Soc. Exper. Biol. & Med. **51**:208-209 (Nov.) 1942.

149. Lazere, B.; Thomson, J. D., and Hines, H. M.: Effect of Atropine upon Atrophy and Neuromuscular Regeneration, Proc. Soc. Exper. Biol. & Med. **53**:83-84 (May) 1943.

150. Solandt, D. Y.; DeLury, D. B., and Hunter, J.: Effect of Atropine and Quinidine Sulphate on Atrophy and Fibrillation in Denervated Skeletal Muscle, Am. J. Physiol. **140**:247-255 (Nov.) 1943.

ject on the effects of atropine sulfate on atrophy of muscles, and the latter group of writers also discuss the effect of quinidine sulfate on atrophy of muscle.

Altschul [151] investigated the question of whether muscular atrophy due to denervation and degeneration could be delayed or avoided by treatment with neostigmine and acetylcholine.

From the standpoint of loss of weight the treatment apparently had no effect, but histologic studies showed definitely that the atrophy was slighter and degenerative phenomena were lacking. These results were true for cats but not for rabbits. He feels that since different species of animals differ in their response there should be differences in the response of persons and also in the response of different muscle groups throughout the body.

Odom, Russel and McEachern [152] discuss the effects of neostigmine on myasthenia gravis and progressive muscular atrophy.

Their conclusions are that the abnormal myograms of patients with myasthenia gravis become normal within forty-five minutes after intramuscular injection of neostigmine methylsulfate. In 3 cases of progressive muscular atrophy a small dose of neostigmine intensified fasciculation. Fasciculation does not occur in normal persons with so small a dose.

Thus the drug possesses a definite value as a diagnostic aid in both of these diseases.

Eaton [153] emphasizes that neostigmine methylsulfate is of value in a diagnostic test for myasthenia gravis because of its strengthening effect and that diagnosis can still further be confirmed by the use of quinine, which has a characteristic weakening effect.

151. Altschul, R.: Effect of Prostigmine and Acetylcholine on Denervated Muscle, with Remarks on Some General Effects of These Drugs, J. Nerv. & Ment. Dis. **97**:549-562 (May) 1943.

152. Odom, G.; Russel, C. K., and McEachern, D.: Studies of Neuromuscular Disorders: Myogram, Blood Cholinesterase and Effect of Prostigmine in Myasthenia Gravis and Progressive Muscular Atrophy, Brain **66**: 1-17 (March) 1943.

153. Eaton, L. M.: Diagnostic Tests for Myasthenia Gravis with Prostigmine and Quinine, Proc. Staff Meet., Mayo Clin. **18**:230-236 (July 14) 1943.

V. TUMORS OF BONE AND OF SYNOVIAL MEMBRANE

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ROCHESTER, MINN.

Classification of Tumors of Bone.—Caldwell [154] presents a classification that is employed at the Baylor Tumor Clinic:

A. Benign tumors of bone
   1. Osteochondromas
   2. Multiple exostoses
   3. Chondromas and chondromyxomas
   4. Osteomas
   5. Benign giant cell tumors
   6. Hemangiomas

B. Malignant tumors of bone
   1. Osteogenic sarcomas
      (*a*) Chondromyxosarcomas
         (1) Primary chondromyxosarcomas
         (2) Chondrosarcomas (secondary)
      (*b*) Periosteal osteoblastic sarcomas
         (1) Sclerosing type
         (2) Osteoid type
         (3) Fibrous type
      (*c*) Fibrosarcomas of bone
      (*d*) Chondroblastic sarcomas (osteolytic)
      (*e*) Endosteal osteoblastic sarcomas (osteolytic)
      (*f*) Malignant giant cell tumors
   2. Ewing sarcomas
   3. Multiple myelomas (Bence-Jones proteinuria present in 50 per cent of cases)
   4. Chloromas, chloroleukosarcomas and chloromyelosarcomas
   5. Reticuloendothelial sarcomas
   6. Chordomas

C. Metastatic tumors of bone and bone marrow
   1. Secondary carcinomas
   2. Lymphosarcomas
   3. Melanosarcomas
   4. Neuroblastomas and retinoblastomas

Budd and MacDonald [155] note confusion relative to the classification of tumors of bone. They present a modified classification as adopted by the Registry of Bone Sarcoma in 1939.

Meyerding [156] discusses briefly certain confusing terms employed and presents his classification of tumors of bone as follows:

154. Caldwell, G. T.: Classification of Bone Tumors, Texas State J. Med. **39**:282-285 (Sept.) 1943.

155. Budd, J. W., and MacDonald, I.: A Modified Classification of Bone Tumors, Radiology **40**:586-588 (June) 1943.

156. Meyerding, H. W.: Classification of Bone Tumors, Proc. Staff Meet., Mayo Clin. **18**:17-18 (Jan. 27) 1943.

NEOPLASMS OF BONE AND LESIONS SIMULATING THEM

I. Lesions simulating neoplasms of bone
  A. Inflammatory lesions
    1. Traumatic lesions (callus; ossifying hematoma)
    2. Infections (syphilis; tuberculosis; osteomyelitis; nonsuppurative osteomyelitis of Garré; Brodie's abscess; myositis ossificans; osteoperiostitis)
  B. Osteitis fibrosa cystica
  C. Metabolic lesions
    1. Hand-Schüller-Christian disease; Gaucher's disease; Niemann-Pick disease; hyperparathyroidism
  D. Nutritional lesions
    1. Rickets; scurvy

II. Neoplasms of bone
  A. Benign osteogenic tumors
    1. Osteoma (exostosis)
    2. Chondroma
  B. Fibroblastic tumors
    1. Benign fibroma
    2. Malignant periosteal and cortical
  C. Giant cell tumors
    1. Benign giant cell tumor
    2. Malignant giant cell sarcoma
  D. Vascular neoplasms
    1. Benign hemangioma (cavernous or plexiform); lymphangioma
    2. Malignant hemangio-endothelioma (diffuse endothelioma or Ewing's tumor); lymphangio-endothelioma
  E. Malignant osteogenic sarcoma (including chondrosarcoma)
  F. Multiple myeloma
  G. Metastatic tumors
  H. Miscellaneous group
    1. Undifferentiated malignant neoplasms
    2. Lymphosarcoma; liposarcoma; erythroblastoma; chloroma; adamantinoma

Lesions Simulating Neoplasms of Bone.—Kernwein and Queen [157] state that solitary eosinophilic granuloma is an uncommon benign destructive lesion of bone, of which there are 19 cases reported in the literature. It has been seen among young or adolescent male patients, with a presenting symptom of swelling or pain or both. The lesion is solitary, and in 12 of the 19 cases it was located in the skull or the ribs. The treatment was surgical, alone or combined with roentgen therapy. They present data on 1 case.

Rogers [158] presents data on 2 cases of cyst of the upper part of the humerus. Treatment consisted of excavating the cystic cavity and packing it with chips of bone, after which two full cortical thickness grafts from the tibia were inserted as struts. The proximal portions of the grafts were placed through the cystic region to extend to the head of the humerus, and the lower ends were fixed by screws to the shaft. No external fixation was used. Satisfactory healing and good functional results occurred in both cases.

Barden [159] presents data on a case of cystic tumor of the proximal phalanx of the little finger of a patient, which had been present for thirty years. There had been slow and progressive swelling. No biopsy was performed, but the roentgenologic picture was suggestive of solitary cyst of the bone or benign giant cell tumor. He draws attention to the paucity of American and English literature concerning irradiation treatment of cysts of bone.

Bennett [160] presents an unusual series of roentgenograms showing the development of a bone cyst of the solitary type. They had been taken nine months apart, between May 1938 and November 1941, as an index of the normal development of a child. The development of the cyst was incidental to the desired records. The first roentgenogram was normal. The following one showed a small defect in the upper part of the tibia, which appeared larger in subsequent roentgenograms. The cyst was removed surgically, and the pathologic report was typical giant cell tumor of bone (benign). There were never any subjective symptoms.

Brugsch [161] presents data on a case of Hand-Schüller-Christian disease. The lesion was discovered during a routine roentgenographic examination of the lungs of an 18 year old Jewish youth. He discusses the differential diagnosis of pseudocystic diseases of bone, which include: (1) hyperparathyroidism; (2) fibrous dysplasia of bone (Lichtenstein; Albright); (3) dyschondroplasia; (4) osteitis deformans; (5) multiple myeloma and metastatic malignant growth; (6) lipidosis: Gaucher's disease, osseous xanthomatosis and Schüller-Christian disease.

Furst and Shapiro [162] discuss the several hypotheses of the causation of fibrocystic disease of bone of the polyostotic type. Although each hypothesis explains in part some manifestation, none gives ultimate and direct proof as to the exact cause. (The relationship of dermal pig-

157. Kernwein, G. A., and Queen, F. B.: Solitary Eosinophilic Granuloma, Surgery **14**:105-110 (July) 1943.

158. Rogers, W. A.: An Operation for Benign Cyst of the Upper Humeral Metaphysis, Arch. Surg. **46**: 759-761 (May) 1943.

159. Barden, S. P.: Bone Cyst Successfully Treated with X-Rays, Radiology **39**:732-733 (Dec.) 1942.

160. Bennett, C. B.: Notes on an Early Bone Cyst, Arch. Surg. **46**:608-610 (May) 1943.

161. Brugsch, H. G.: Pseudocystic Bone Disease (Lipidosis of the Bones), Bull. New England M. Center **4**:284-290 (Dec.) 1942.

162. Furst, N. J., and Shapiro, R.: Polyostotic Fibrous Dysplasia: Review of the Literature with Two Additional Cases, Radiology **40**:501-515 (May) 1943.

mentation, pathologic changes of bone and sometimes sexual precocity is an unusual one and perhaps cannot be completely evaluated in a single theoretic statement.) They mention the fact that the results of all laboratory examinations may be within normal limits. The condition must be distinguished from hyperparathyroidism, regional fibrocystic disease, dyschondroplasia (Ollier), rarely Paget's disease, leontiasis ossea and Hand-Schüller-Christian disease. They present data on 2 cases, in 1 of which the patient was a boy of 15 years, without endocrine disorders or pigmentation. Roentgenographic examination of the bones was done because of facial asymmetry and old injury to the arm. The initial diagnosis was osteitis fibrosa cystica. In the other case the patient was a 17 year old girl. There was a history of menses at 3 years of age and full maturation of secondary sexual characteristics at 9 years. The patient was examined because of swelling of the elbow after injury. Previous exploration of the parathyroid glands had revealed no abnormality. The results of all laboratory studies were within normal limits except for some variation in the results of the phosphatase tests in the first case.

Lesions of Tendon Sheath.—Shepherd [163] presents data on a case of osteochondroma arising from the sheath of the flexor tendon of the index finger. He states that tumors of the sheaths are uncommon, the most frequent being giant cell tumor and xanthoma. A review of data on the cases in the literature reveals that osteochondromas are observed usually near the bony insertion of the tendon, whereas in this case the tumor was located near the base of the index finger. Microscopic examination showed that the tumor consisted of hyaline cartilage with some calcification in the central portion.

Cristol and Gill [164] present data on a case in which the patient had extensive xanthoma of the tendon sheath of the left foot. Operation was performed at the University of Pennsylvania Hospital. The condition presented difficulties in diagnosis and treatment; a pathologic diagnosis of "mixed cell sarcoma" and of "xanthomatous tissue" had been made on two occasions, and roentgen therapy had failed to control the growth of the lesion, so that finally amputation of the left leg was performed. Alteration in lipid metabolism was the primary etiologic factor, trauma or infection or both being secondary factors.

163. Shepherd, J. A.: Osteochondromata of Tendon-Sheaths: A Case Arising from the Flexor Sheath of the Index Finger, Brit. J. Surg. **30**:179-180 (Oct.) 1942.

164. Cristol, D. S., and Gill, A. B.: Xanthoma of Tendon Sheath, J. A. M. A. **122**:1013-1014 (Aug. 7) 1943.

Benign Neoplasms of Bone.—Enchondroma: Jaffe and Lichtenstein,[165] in their customary precise manner, present data on 28 cases of solitary benign enchondroma of bone. They emphasize the fact that the tumor occurs most often in the bones of the limbs and especially in the phalanges of the fingers, the metacarpal bones, the humerus and the femur. The tumor usually has its nidus in the metaphysial portion of the bone. It may extend to the epiphysis after fusion. It usually thins and distends the cortex, producing a definite bulge. Symptoms are minimal, usually only the bulging of a finger laterally with slight tenderness or ache. Roentgenographic study reveals the typical region of rarefaction, usually without evidence of calcification, but small dots of calcified deposits may be present in tumors of the large bones. The ultimate diagnosis of benign enchondroma rests on the microscopic finding of, usually, mononuclear cartilage cells, the nucleus being small in relation to the cell, and any binuclear cells, especially, showing small nuclei. Enchondroma of long tubular bones may undergo malignant changes, of which the early manifestations are microscopic only and consist of cells with plump nuclei or large cartilage cells with especially large nuclei.

Chondroma: Olsman and Lev [166] present data on a case of chondroma of the sacrococcygeal region. The patient was an Italian man, 73 years of age, who had psychosis with cerebral arteriosclerosis. He had had an injury to the base of his spinal column eleven years prior to admission to the hospital and had had two operations. Roentgenographic examination revealed cystic degeneration of the sacrum with calcified regions. In 1940 laparotomy disclosed that the peritoneal cavity contained fecal-smelling fluid. The patient died the day following the operation. Necropsy showed involvement of the peritoneum with peritonitis. Otherwise the usual symptoms and signs of a slow growing sacrococcygeal chondroma with anterior and posterior extension were present: (1) pain; (2) palpable mass observed on rectal examination; (3) roentgenologic findings of destruction of the sacrum, and (4) constipation.

Lehmann [167] reports data on a case of "myxofibroma" of the right tibia in which there

165. Jaffe, H. L., and Lichtenstein, L.: Solitary Benign Enchondroma of Bone, Arch. Surg. **46**:480-493 (April) 1943.

166. Olsman, L., and Lev, M.: Sacrococcygeal Chordoma: Report of a Case, Am. J. Surg. **60**:115-118 (April) 1943.

167. Lehmann, O.: "Myxofibroma" of Bone. Report of a Case Involving a Tibia, Bull. Hosp. Joint Dis. **4**:12-15 (April) 1943.

was involvement of the upper part of the diaphysis. Operation was done on Nov. 4, 1942. The condition had apparently followed an injury twelve years previously. The operation consisted of excision and swabbing of the wound with 50 per cent solution of zinc chloride. The patient had obtained an excellent result at the time of Lehmann's report. The author states that 3 other such cases had been observed in the Hospital for Joint Diseases, in all of which the lesions had had identical histologic features. There had been no recurrence of the lesion in any of the cases.

Giant Cell Tumor.—Lopez [168] discusses giant cell tumors of the long bones. He states that these tumors are frequently found in patients between 16 and 54 years of age and are located in the epiphysis of the long bones. There is a history of trauma or of an inflammatory process. The tumor consists of giant cells, fibrous tissue and vessels. Pain and the presence of the tumor are the principal findings on examination; no fever or loss of weight is noticed. The condition should be distinguished from cyst, fibrous osteitis (von Recklinghausen's disease) and malignant tumor of bone. Malignant tumors are subdivided into the following: osteogenic sarcoma, Ewing's tumor and myeloma. Treatment should be conservative, and in the event that it fails amputation is indicated.

Levine [169] reports data on the sixteenth case of giant cell tumor of the patella in the literature. The patient was a white man 31 years of age, who complained of pain over the medial aspect of the right knee and tenderness of the knee cap which had followed an injury one year previously. Examination revealed atrophy of the thigh and calf with slight swelling of the knee. Roentgenographic study revealed irregular cystic regions occupying two thirds of the patella. The patella was excised and a cast applied. The postoperative course was uneventful. Trauma was apparently the cause in this case.

Gershon-Cohen [170] reviews data on 29 cases of giant cell tumor in which the late results of roentgen therapy were good, yielding cures in possibly more than 85 per cent of the cases (follow-up reports varied from five to thirteen years after treatment). Less morbidity and better recalcification of the tumor occur than after surgical treatment, and the complications of recurrence and infection may be prevented. Weight bearing should be avoided during treatment, and afterward until healing has progressed fairly well. Therapy need not be given in large doses or for a long time.

Gendreau and Pinsonneault [171] report on pathologic forms of osteoclasis (osteoclastoma, giant cell tumor and epulis) and clinical manifestations of osteitis fibrosa. They explain the pathogenesis and the clinical manifestations of the so-called processes of osteofibrosis on the basis of the physiologic activity of the osseous tissue. This is said to be in a constant state of renewal by means of a process of destruction and reconstruction, that ends in a gradual mechanical perfection of the skeleton. Destruction takes place slowly and completely by osteoclasis or quickly and partially by osteolysis. Regeneration is prompt and direct by fibrous ossification. Any imbalance between the two main processes leads to a pathologic condition known as osteofibrosis. This, they consider, occurs in three stages: 1. Destruction (patchy or diffuse) by osteolysis, with the main structure of the bone left intact, or by osteoclasis, with nothing left of the dead tissue but a hemorrhagic focus that can take the shape of a cystic cavity. Calcium is liberated in both instances, and the liberated calcium may remain localized or may produce hypercalcemia. 2. Fibrous proliferation. This may take its origin from the connective tissue left by osteolysis, or it may be a new formation originating in the hemorrhagic focus left by osteoclasis (polymorphic roentgenologic aspects of Paget's disease and encapsulated and areolar aspect of giant cell tumor). 3. Calcification of the preosseous substance. This may occur early or late.

The authors emphasize the fact that a focus of osteitis fibrosa may show simultaneously all three stages in its different parts. In Paget's disease destruction is marked at the onset and calcification at the end. There is not much liberation of calcium, but the blood phosphate level may be elevated as a result of the increased constructive activity. In von Recklinghausen's disease destruction is more extensive than in Paget's disease, and consequently functional changes and deformities are greater. Calcification decreases with progress of the disease, and the calcium level is always high in the blood, while the phosphate level shows little change. They present a table of all known forms of osteofibrosis. The clinical

168. Lopez, C. P.: Tumores oseos a células gigantes de los huesos largos, Día méd. **15**:388-395 (April 26) 1943.

169. Levine, M. A.: Giant Cell Tumor of the Patella: Case Report, Am. J. Surg. **62**:286-289 (Nov.) 1943.

170. Gershon-Cohen, J.: Giant-Cell Tumors: Radiation Therapy and Late Results, Radiology **41**:261-267 (Sept.) 1943.

171. Gendreau, J. E., and Pinsonneault, G.: Considérations sur les formes pathologiques de l'ostéoclasie et les manifestations cliniques de l'ostéite fibreuse, avec quinze observations personnelles, Union méd. du Canada **72**:1032-1056 (Sept.) 1943.

manifestations of osteofibrosis vary with the nature of the bone tissue in which they take place: Its manifestations in the bones of a child are different from those in the bones of an adult; its character in the long bones is not the same as it is in the short ones. Osteoclastic lesions, such as giant cell tumors, do not occur in bones of membranous origin, such as the frontal and the parietal bone. Those described as present in the upper maxillary region actually come from the ethmoid bone, which originates from cartilage. Osteoclastomas are most frequent and malignant in bones in which spongy tissue is abundant, and their malignancy decreases when they occur in the long bones far from the epiphysis. They are also more benign in the proximity of fibrous tissue and extremely benign in the flat bones. In some cases the origin of giant cell tumor may be related to a softening of the periosteum and compact bone, and their malignancy increases with age, because of a limited activity of the periosteum in old people. The authors illustrate their paper with data on 15 personal cases, 2 of which were cases of von Recklinghausen's disease, 2 of giant cell tumor, 7 of osteoclastoma and 4 of epulis.

Vascular Neoplasms.—Angioma: Zadek[172] reports data on a case of angioma of the tibialis anterior muscle in a girl of 14 years. She had had pain when walking and tenderness over the region of the growth but no other symptoms. Roentgenographic study gave negative results. The whole width of the muscle was transected above and below the tumor. Healing was uneventful, and complete function of the muscle returned.

Hemangioma: Bruno[173] reports data on a case of hemangioma of a vertebra and states that hemangiomatous processes occur in 10 per cent of vertebral columns but do not often cause compression of the cord. The clinical syndrome is not characteristic, and the severity of it depends on the degree of compression. Roentgenographic examination reveals a vertical striated appearance in the body of the vertebra and a honeycombed rarefaction in the pedicles and laminas. It is estimated that a third of the body must be involved before roentgenologic diagnosis is possible. He states that his patient had obtained considerable relief following roentgen therapy up to the time of his report.

Blackford[174] also reports data on a case of hemangioma of a vertebra in which there was compression of the cord and in which a cure of fourteen years' duration had been obtained following roentgen therapy. He states that hemangioma of a vertebra is seen in more than 10 per cent of routine autopsies and occurs more frequently in older persons and women. It causes symptoms relatively often in young men. Irradiation is advised by most doctors, as surgical treatment carries too high a mortality rate. He states that his patient had an extremely vascular tumor which was diagnosed pathologically as a probable osteogenic sarcoma of telangiectatic type. The patient received roentgen therapy and recovered from his symptoms. Therefore, clinically this was a hemangioma of a vertebra. The patient was accepted by the army fourteen years subsequently.

Kaplan[175] reports data on a case of hemangioma of the elbow in which treatment by means of radium was given at an early age. The patient, an infant aged 10 weeks, had a large hemangioma over the outer and the inner surface of the elbow. Radium treatment was given, and the patient was followed for nine years. There was no clinical or roentgenologic evidence of any deleterious effect on the centers of growth or on the function of the joint. The author concludes that fear of adversely affecting growing bones of children with radium therapy is fallacious if irradiation is properly and expertly administered.

Cobey[176] discusses data on 4 cases of hemangioma of the knee joint. He draws attention to the fact that this is not a rare condition and should be considered in any case in which swelling of the knee joint is a presenting symptom. The presence of other hemangiomas on the body and intermittent swelling of the knee with decrease in swelling on elevation of the limb point to the probability of this type of tumor of the joint. The tumor may be in the synovial membrane or the capsule. Treatment is surgical excision if the lesion is small or roentgen therapy if it is extensive. He expresses the belief that biopsy specimens of all tumors of this type should be taken for diagnosis and before roentgen therapy is given.

172. Zadek, I.: Angioma of the Tibialis Anterior: A Case Report, J. Bone & Joint Surg. **25**:930-931 (Oct.) 1943.

173. Bruno, F. E.: Hemangioma of the Vertebrae: Report of a Case, Bull. New England M. Center **5**:237-239 (Oct.) 1943.

174. Blackford, L. M.: Hemangioma of Vertebra with Compression of Cord: Report of a Case Cured with Radiation Fourteen Years Ago, J. A. M. A. **123**:144-146 (Sept. 18) 1943.

175. Kaplan, I. I.: Hemangioma of the Elbow Successfully Treated with Radium at an Early Age, Am. J. Dis. Child. **65**:785-787 (May) 1943.

176. Cobey, M. C.: Hemangioma of Joints, Arch. Surg. **46**:465-468 (April) 1943.

[ED. NOTE.—Benign angiomas are radiosensitive, and repeated exposure to roentgen rays at regular intervals for months appears to be a satisfactory method of treatment. Microscopic examination and the opinion of an expert pathologist are advisable in those cases in which biopsy does not entail any great danger to the patient.]

Ewing's Sarcoma: In a report on the roentgenologic aspects of Ewing's sarcoma of bone marrow Swenson [177] states that there is great variation in its roentgenologic manifestations and hence there is no typical roentgenologic picture and a definite diagnosis can rarely be made from roentgenographic examination alone. The disease may spread from the site of primary involvement throughout the soft tissue of the marrow cavity without producing destruction of bone, which would betray its entire extent. Evidence suggests that a combination of surgical and roentgen therapy will give the best results with this type of lesion.

[ED. NOTE.—I am inclined to agree with this author that there is no typical roentgenographic picture of Ewing's sarcoma. I have pointed out that the roentgenographic findings are frequently confused with those in osteomyelitis. While the microscopic interpretation by the pathologist is advisable for lesions of this type, the lesion is radiosensitive, and diagnostic irradiation may be employed.]

Stout [178] presents a discussion of the pathologic features and the histogenesis of Ewing's tumor of bone marrow. The principal pathologic features of this lesion of the bone marrow are given, and the hypotheses of Ewing, that the tumor is derived from vascular or perivascular endothelium, and of Oberling, that it is derived from young recticular cells, are discussed. Although the author favors the latter hypothesis, he believes that no conclusions regarding histogenesis are possible with the present knowledge.

Muscolo [179] discusses the difficulties encountered in the diagnosis of Ewing's tumor and osteomyelitis. The roentgenologic findings in Ewing's sarcoma during the early stages of the disease are similar to those in subacute and chronic osteomyelitis. After the initial period of reaction Ewing's tumor could be confused with acute osteomyelitis. Biopsy must be performed in all cases, because the clinical and the roentgenographic findings are not sufficient to rule out either one definitely. For a tumor of the body of a vertebra the true nature of which is doubtful, he uses the puncture biopsy, according to the technic of Valls, Ottolenghi and Schajowiz.

Beck [180] presents a report concerning Ewing's sarcoma and points out that the diagnosis is based mainly on the clinical and the roentgenologic symptoms rather than on a circumscript histologic appearance. Furthermore, he feels that there exist different opinions about the histogenesis of this type of tumor, which is expressed in various names, like angioendothelioma, diffuse endothelioma, reticuloendothelioma and primary lymphoma of bone. The author then describes his observations in 5 cases of Ewing's sarcoma with a rosette-like structure of the tumor cells. All the sarcomas showed the same picture: There was a group of radially arranged cells with the cytoplasm toward the center. The cytoplasm had a fine granular appearance, containing fine collagen fibers and droplet formation. All of his cases were proved instances of the Ewing type of sarcoma. On the basis of his observations, the author points out the bearing of the rosette-like structure on the hitherto various opinions of the histogenesis of these tumors. On this basis they are not endothelioma, lymphoma nor reticuloendotheliosarcoma. However, it is also impossible to come to an explanation of the histogenesis with the foregoing microscopic observations. The possibility of the tumor's being an immature osteoblastosarcoma is mentioned. The question arises whether the clinical and roentgenologic picture of Ewing's sarcoma may exist with histologically different tumors. There is no definite answer, but it is more likely that Ewing's sarcoma represents a clinical, roentgenologic and histologic circumscript symptom complex.

Barden [181] discusses the similarity of the clinical and roentgenologic features of Ewing's sarcoma and sympathetic neuroblastoma as observed in children and reports data on 4 cases, in 2 of which the tumor was Ewing's sarcoma and in 2 sympathetic neuroblastoma. There was roentgenologic evidence of widespread tumor of bone, and it was clinically impossible to make a differental diagnosis preceding death of the patients.

177. Swenson, P. C.: The Roentgenologic Aspects of Ewing's Tumor of Bone Marrow, Am. J. Roentgenol. **50**:343-353 (Sept.) 1943.

178. Stout, A. P.: A Discussion of the Pathology and Histogenesis of Ewing's Tumor of Bone Marrow, Am. J. Roentgenol. **50**:334-342 (Sept.) 1943.

179. Muscolo, D.: Sarcoma de Ewing y osteomielitis difficultades de diagnostico, Rev. Asoc. méd. argent. **57**: 599-603 (Aug. 30) 1943.

180. Beck, W.: Ueber das Vorkommen rosettenartiger Bildungen in Knochensarkomen von der Art des sog. Ewing-Sarkoms, Virchows Arch. f. path. Anat. **308**: 750-775, 1942.

181. Barden, R. P.: The Similarity of Clinical and Roentgen Findings in Children with Ewing's Sarcoma (Endothelial Myeloma) and Sympathetic Neuroblastoma, Am. J. Roentgenol. **50**:575-581 (Nov.) 1943.

A solitary tumor of bone diagnosed as Ewing's sarcoma should be treated as if the lesion were secondary to an abdominal tumor, whether the presence of the latter can be proved or not. Accordingly, amputation for cure should probably not be attempted and roentgen therapy to the retroperitoneal structures should be routine.

Malignant Osteogenic Sarcoma.—MacDonald and Budd [182] present a review of data on 118 cases of osteogenic sarcoma in which five year cures were obtained from the Registry of Bone Sarcoma. In 1941 the Registry of Bone Sarcoma reported 1,022 registered cases of "osteogenic" sarcoma. In 654 cases the lesion had been treated five years or more prior to 1941 and in only 97, or 14.8 per cent, were five year cures obtained. One hundred and fifteen instances of chondrosarcoma, with 21 five year cures (11 per cent), had been found in the Registry, with other cases of chondrosarcoma undoubtedly remaining unidentified without a complete survey of the entire collection. This group of 118 cases of a highly lethal type of neoplasm in which five year cures had been obtained offered a challenge to a critical review of the clinical and microscopic features and of the methods by which the lesions had been treated. It was anticipated that differences might be found in a comparison of a series of cured lesions with a series of uncured lesions, to be unselected except for a comparable regional incidence. Through the cooperation of the Registry it was possible for them to study the case records, the roentgenograms and the microscopic slides of the entire group of cured lesions, but the present emergency interrupted the study, with only 47 cases of fatal osteogenic sarcoma reviewed.

They present two tables which give the classification of the Registry of Bone Sarcoma for 1923 and for 1939 and suggest a modification, as follows:

	Malignant		Benign
Osteogenic series	(*a*) Osteosarcoma (*b*) Chondrosarcoma (*c*) Fibrosarcoma	Osteogenic sarcoma	Osteoma Chondroma

Several illustrative photomicrographs are shown.

[Ed. Note.—These authors have again introduced the term "osteosarcoma," which had been discarded in recent years by the Registry and other authorities, and have employed it to signify sarcoma characterized by production of bone. They employ "osteogenic sarcoma" as a generic designation for the triad of connective tissue sarcomas primary in bone, the third member of which is chondrosarcoma. They state that an analysis of the results in osteogenic sarcoma indicates that true osteosarcoma is an almost uniformly fatal form of neoplasm, that fibrosarcoma is a distinctly less malignant form of osteogenic sarcoma and that chondrosarcoma occupies a median position, being cured and fatal in approximately equal proportions.]

Luck [183] presents an excellent roentgenologic and microscopic pathologic review of neoplasms which produce bone or cartilage. He includes osteoma, chondroma, osteochondroma and the malignant types osteogenic sarcoma and chondrosarcoma. He discusses modern beliefs on surgical treatment and experiences regarding treatment.

Pomeranz [184] presents a paper on the roentgenographic diagnosis of osteogenic sarcoma. He gives the criteria for the roentgenologic diagnosis and the differential diagnosis. He emphasizes the fact that the roentgenogram should be interpreted in relation to the clinical findings and the history. He states that statistically 90 per cent of these lesions occur in the long bones of the lower portion of the limb and 10 per cent in the upper part of the limb and that the disease is essentially one of youth. The osteolytic type of tumor grows more rapidly than the osteoblastic. The tumors as a group produce simultaneously destruction of bone and bizarre formation of new bone.

Chondrosarcoma: Lichtenstein and Jaffe [185] present a discussion of chondrosarcoma of bone. In comparison with osteogenic sarcoma, chondrosarcoma is less common, appears at a later age and is slower to metastasize to the lungs. In the former the basic proliferating connective tissue merges directly into neoplastic osteoid tissue and bone, although cartilage may be formed. In the latter the basic proliferating tissue is full-fledged cartilage, although the matrix may become calcified and ossified. Early chondrosarcoma may be diagnosed microscopically if the definite signs of malignant growth are looked for carefully. They are (1) many cells with plump nuclei, (2) more than an occasional cell with two such nuclei and (3) giant cartilage cells with large single or multiple nuclei or with clumps

182. MacDonald, I., and Budd, J. W.: Osteogenic Sarcoma: I. A Modified Nomenclature and a Review of 118 Five Year Cures, Surg., Gynec. & Obst. **77**:413-421 (Oct.) 1943.

183. Luck, J. V.: A Correlation of Roentgenogram and Pathological Changes in Ossifying and Chondrifying Primary Osteogenic Neoplasms, Radiology **40**:253-275 (March) 1943.

184. Pomeranz, M. M.: The Roentgenographic Diagnosis of Osteogenic Sarcoma, Bull. Hosp. Joint Dis. **4**:3-11 (April) 1943.

185. Lichtenstein, L., and Jaffe, H. L.: Chondrosarcoma of Bone, Am. J. Path. **19**:553-589 (July) 1943.

of chromatin. It can often be proved that a chondrosarcoma has developed from a benign lesion, either an enchondroma or an osteocartilaginous exostosis (osteochondroma). In their paper they present studies of cases, photographs of gross lesions and roentgenograms and microscopic views of 10 central and 5 peripheral chondrosarcomas. Chondrosarcoma spreads late, and when it does spread it is usually via the venous channels by intravascular growth and extension, although it often gives rise to parenchymal metastatic growths, usually only to the lungs. In determining the malignancy of a chondroma, attention should be paid to regions which are viable and not heavily ossified or calcified. Since cell division in chondrosarcoma tends to be amitotic, search for mitotic figures is not extremely important. Roentgenologic signs of malignancy of an enchondroma are an irregularly mottled and calcified shadow in the interior of the bone and a fuzzy area of localized destruction of the cortex. Malignant changes in an osteochondroma are indicated by a dense, blotchy appearance, usually with ragged, irregular, dense streaks extending away from the lesion. Radical surgical treatment is recommended; irradiation is not.

Osteoclastoma.—Brailsford [186] considers the treatment of osteoclastoma to be primarily roentgen irradiation. He believes that biopsy is not necessary, since the diagnosis can be made by roentgenography. He suggests that roentgen therapy be given before amputation, if amputation is deemed necessary.

Sarcoma of Patella.—Bowen [187] reports an unusual case of primary tumor of the patella. At necropsy the tumor was classified as a sarcoma, and the author believes that it might have developed from a giant cell tumor.

Primary Malignant Tumor of Bone.—Shallow, Raker and Fry [188] analyze data on 53 cases of primary malignant tumor of bone observed at the Jefferson Medical College Hospital over twenty years. This series consisted of 43 cases of osteogenic sarcoma, 4 of Ewing's sarcoma, 3 of multiple myeloma and 1 each of adamantinoma, liposarcoma and probably malignant giant cell tumor. In 6 (18.7 per cent) of the 33 cases of osteogenic sarcoma in which adequate operation could be performed the patients survived five years; amputation was the most frequent type of treatment employed; roentgen and radium therapy and Coley's toxins (a mixture of erysipelas and Bacillus prodigiosus toxins) were also employed, with or without surgical treatment; in 18 cases amputation alone was performed. In 8 cases in which the patients lived, the longest period of survival was twelve and a half years. A brief history of these cases is presented.

All 4 of the patients who had Ewing's sarcoma died. One of them died postoperatively, and in 3 metastasis developed, resulting in death. One patient who had adamantinoma had noticed the lesion after trauma to the tibia. Amputation was performed on this patient, and death occurred twenty-two months following the onset of symptoms. Sixteen cases of giant cell tumor were studied, in which treatment was varied and consisted of operation, roentgen therapy or a combination of operation and roentgen therapy. In 1 of these cases the tumor was considered malignant and astragalectomy was performed; the patient was living seven years later.

The authors found a high incidence of trauma and believe it "seems to play some role in the genesis of bone tumors." They stress the danger of diagnostic biopsy and believe arteriography a great diagnostic aid, quoting Inclan. They believe that when amputation is indicated it should be performed at the "earliest optimum time, rather than as soon as the diagnosis has been made."

[ED. NOTE.—The difficulties in attempting to arrive at definite scientific conclusions from a study of a limited number of cases of tumors of various types is obvious.]

Osteogenic Sarcoma of the Vertebrae Secondary to Paget's Disease.—Campbell and Whitfield [189] present data on 3 cases of osteogenic sarcoma of the vertebrae in patients suffering from Paget's disease. In all 3 cases the condition was characterized by increasingly severe backache of short duration with neurologic changes in the lower part of the trunk and in the extremities. Careful search of the literature by the authors revealed but 3 cases of sarcoma of the vertebrae. In all of these there was involvement of other bones, so that it was difficult to determine the primary lesion. On the other hand, their search revealed an incidence of osteogenic sarcoma of various bones in Paget's disease of 7.5 to 14 per cent, according to differ-

186. Brailsford, J. F.: Treatment of Osteoclastoma, Lancet **1**:776-777 (June 19) 1943.

187. Bowen, F. H.: Sarcoma of the Patella: Report of a Case, J. Florida M. A. **30**:20-22 (July) 1943.

188. Shallow, T. A.; Raker, N., and Fry, K.: Primary Malignant Tumors of Bone with Special Reference to Osteogenic Sarcoma, J. Internat. Coll. Surgeons **6**: 89-98 (March-April) 1943.

189. Campbell, E., and Whitfield, R. D.: Osteogenic Sarcoma of Vertebrae Secondary to Paget's Disease: Report of Three Cases with Compression of Spinal Cord and Cauda Equina, New York State J. Med. **43**:931-938 (May 15) 1943.

ent authors. Radiation or surgical treatment of such tumors produces little or no improvement. In 2 cases in this series the patients underwent operation and died four or five months later. In the other case the patient refused operation and died four months after the onset of symptoms.

Aneurysm Simulating Malignant Tumor.—Kirshbaum and Kraft [190] present data on an unusual aneurysm which simulated a malignant tumor of bone in that there was destruction of the upper portion of the fibula by pressure from the aneurysm of the tibial artery and tumefaction of the soft tissue. The correct diagnosis was made at necropsy. The clinical and roentgenologic diagnosis was osteolytic sarcoma of the fibula.

Development of Bone in Relation to Formation of Neoplasms.—Haldeman [191] presents a paper on the development of bone in relation to the formation of neoplasms. He reiterates the findings of Geschickter and Copeland and gives their classification of tumors of bone. A discussion by Bromer includes the part trauma plays in the genesis of periosteal and osseous tumors.

Multiple Myeloma.—Toth and Wintermantel [192] review the general features of solitary myeloma and give data on a case of an apparent solitary myeloma of the right pubic bone with local expansion and subsequent generalization. Histologically it was a plasma cell type of myeloma. There was improvement following roentgen therapy, contrary to the general opinion as to the value of roentgen therapy for this condition.

Metastatic Tumors.—Koenig and Culver [193] discuss the value of roentgen therapy for carcinomatous metastasis to bone and believe that surgeons and clinicians lack enthusiasm for the use of roentgen therapy when a patient manifests metastasis to bone. The results obtained are alleviation of pain, improvement of general condition, prolongation of life and regression of the lesion.

Cleveland and Knox [194] present a case of bilateral carcinoma of the adrenal cortex with metastasis to the iliac bone in a man aged 57 who complained of pain in the right hip with extension into the leg. The pain had followed an injury which had occurred six months before. There had been loss of weight. A punch biopsy had been done and a diagnosis of tumor made. The roentgenograms revealed a destructive lesion of the right iliac bone; the pulmonary fields were clear. In an exploratory operation tissue was removed from the iliac crest; frozen sections were examined and reported as probable sarcoma. A high temperature developed; however, no bleeding from the wound occurred. The patient was treated for shock. He remained unconscious until death occurred, on the second postoperative day.

Necropsy showed the following picture: The adrenals were both practically destroyed and had been replaced by thinly encapsulated tumor masses, the right being 7 by 7 by 5 cm. and the left slightly smaller. They were entirely distinct from the kidneys and adjacent fat. In the anterior part of the right iliac bone the hemorrhagic cavity formed by the removal of tissue for biopsy was found filled with blood clots. The adjacent bone was soft, friable and obviously infiltrated by tumor over an area 4 by 6 cm. Outside the bone large, soft lobulated masses of tumor extended down through the gluteus medius muscle. Here the growth was white, opaque and homogeneous except for a few hemorrhagic regions. The diagnosis was bilateral adrenal carcinoma; metastasis to the right iliac bone and adjacent muscles; adenoma of the right kidney, and bronchopneumonia.

The authors also present a review of the literature. They give a summary of 49 cases reported. In these 49 cases 18 of the tumors occurred in men, 23 in women and 8 in children. In 5 cases the tumors were bilateral. In 40 of these 49 cases the authors were reasonably certain of the site of origin; 14 tumors had been primary on the right side and 26 on the left. They state that the prognosis is poor; the tumor metastasizes by way of the blood stream and grows rapidly. There is a high mortality rate following operation. Of a total of 40 patients who underwent operation, 50 per cent died shortly thereafter, usually within forty-eight hours. Metastasis, as shown by 18 necropsies,

190. Kirshbaum, J. D., and Kraft, G. L.: Traumatic Arteriosclerotic Aneurysm of the Tibial Artery Simulating an Osteogenic Sarcoma of the Fibula: Case Report, Ann. Surg. **117**:793-797 (May) 1943.

191. Haldeman, K. O.: Development of Bone in Relation to the Formation of Neoplasms, Radiology **40**:247-251 (March) 1943.

192. Toth, B. J., and Wintermantel, J. A.: An Apparently Solitary Myeloma of Bone with Subsequent Generalization: Favorable Response to Irradiation with Unusual Reactions, Radiology **41**:472-477 (Nov.) 1943.

193. Koenig, E. C., and Culver, G. J.: The Value of Roentgen Therapy in Carcinomatous Metastases to Bone, Radiology **41**:38-41 (July) 1943.

194. Cleveland, M., and Knox, L. C.: Bilateral Carcinoma of the Adrenal Cortex with Metastasis to the Iliac Bone, Arch. Surg. **47**:192-202 (Aug.) 1943.

occurred most frequently in the lungs, liver and lymph nodes.

Toumey [195] discusses metastatic malignant lesions of the spinal column and reviews data on 95 patients seen at the Lahey Clinic from 1936 to 1940 with roentgenographic evidence of metastasis. Spinal metastasis was twice as prevalent among female as among male patients; it was usually the result of carcinoma of the breast or prostate, other sources being unusual. He believes that roentgenographic examination should be performed in all cases in which the patient has pain in the back and that roentgen therapy should be employed if there is clinical spinal metastasis, even when the roentgenograms are reported normal. He believes that roentgen therapy is the most valuable treatment and that results following the use of cobra venom have been disappointing. Chordotomy and subarachnoid injection of alcohol are valuable in cases in which the patient has intractable pain. Orchiectomy is of value in treating carcinoma of the prostate. Braces, salicylates, codeine and, in cases in which the disease has reached the later stages, dihydromorphinone hydrochloride are helpful adjuvants.

Sinberg [196] reports an interesting case of metastasis to a metacarpal bone from a carcinoma of the testicle. The destructive lesion was situated in the fourth metacarpal bone of a man 64 years of age. The roentgenographic diagnosis was a malignant lesion, and several pathologists reported that the tissue showed Ewing's sarcoma. There was regression of the tumor with roentgen therapy, but later a tumor of the left testicle was discovered, and orchiectomy was performed. On comparison, the tissue from the metacarpal bone and from the testicle was identical, and a diagnosis of carcinoma was made. Still later a mass developed in the right axilla, which showed regression following roentgen therapy.

Epidermoid Carcinoma of the Tibia.—Kraft [197] reports data on 2 interesting cases of epidermoid carcinoma of the tibia with pathologic fractures. Amputation was performed with the limb under refrigeration anesthesia. One lesion arose from a chronic ulcer and one from a fistula or an osseous sinus. In his review of the literature he found the tibia the most frequent location of this lesion. Ulcer carcinoma occurs most frequently among women, while fistulous carcinoma is observed most frequently in men of advanced age and in persons with osteomyelitis of thirty to forty years' duration. He believes that amputation usually is indicated and that the prognosis is favorable. He refers to an article by Dockerty and Meyerding in which they discuss adamantinoma and conclude:

> **The fact that adamantinoma is closely related to the epidermoid carcinoma finds further corroboration in the following common characteristics: (1) Long history of chronic irritation with episodes of either initial or aggravating trauma. (2) Sites of predilection in the tibia, jaw bones and skull. (3) Development in a bone cyst or osseous sinus. (4) Tendency to remain localized and absence of distant metastases in most cases.**

Comments and Queries on Primary Benign and Malignant Tumors of Bone.—Meyerding [198] presents his classification of lesions simulating neoplasms and true neoplasms of bone. He further lays emphasis on the value of the material accumulated by the Registry of Bone Sarcoma of the American College of Surgeons and by the larger medical centers. Conclusions of real value can be drawn only from records which provide facts concerning the history and the clinical and laboratory findings together with the surgical, microscopic and postoperative data and which contain all the essential information. He appreciates the value of clinical and roentgenologic findings and states that experience has shown that the correct diagnosis and the gravity of the prognosis may not be recognized in some cases from these findings alone. In spite of the surgeon's and the pathologist's best efforts erroneous diagnosis may be made and the true nature of the lesion not discovered until death and necropsy. The close cooperation of the physicians in the various fields of medicine, in surgery and in the laboratory is necessary in arriving at an accurate diagnosis and in giving the patient maximal benefit. The bulk of the paper is concerned with a series of questions and answers. Frank replies are given, and the factors that influence the diagnosis and the prognosis and the value of various forms of treatment of tumors of bone are discussed. Seven illustrative cases with roentgenograms are presented.

Diagnosis in Primary Tumors of Bone.—Carrell [199] emphasizes the necessity of the routine examination: complete history of illness, ade-

195. Toumey, J. W.: Metastatic Malignancy of the Spine, J. Bone & Joint Surg. **25**:292-305 (April) 1943.

196. Sinberg, S. E.: Metastasis to a Metacarpal Bone from a Carcinoma of the Testicle, Bull. Hosp. Joint Dis. **4**:31-35 (April) 1943.

197. Kraft, E.: Epidermoid Carcinoma of the Tibia: Report of Two Cases, Am. J. Roentgenol. **50**:602-608 (Nov.) 1943.

198. Meyerding, H. W.: Comments and Queries on Primary Benign and Malignant Tumors of Bone, S. Clin. North America **23**:1012-1029 (Aug.) 1943.

199. Carrell, W. B.: Diagnosis in Primary Bone Tumors, Texas State J. Med. **39**:289-290 (Sept.) 1943.

quate roentgenograms, laboratory studies and biopsy. He feels that biopsy should be performed by a pathologist who is interested in tumors and is equipped to make his report from frozen sections. No harmful effects have been observed in cases in which operation is delayed after biopsy so that the entire specimen may be studied, if such a procedure is deemed advisable. He presents data on 3 cases.

Treatment.—Coley [200] discusses indications for surgical treatment of tumors of bone. He believes that surgical treatment should be primarily conservative for the following benign lesions: (1) solitary osteitis fibrosa cystica; (2) giant cell tumors in accessible locations, for which roentgen therapy is not preferred by this author; (3) osteochondroma; (4) central chondroma, which tends to recur and to become malignant, lesions in the phalanges being exceptions, and (5) myxoma and xanthoma. Conservative surgical treatment is occasionally justifiable for the following growths: (1) parosteal osteogenic sarcoma or sarcoma beginning in osteochondroma; (2) tumors of the scapula of low grade malignancy, and (3) tumors involving a metacarpal bone or a phalanx in the hand or foot. Radical surgical treatment is advisable for malignant lesions. Amputation or disarticulation should be performed early, before metastasis has occurred. He believes that histologic proof by aspiration biopsy should be obtained first and that presurgical roentgen therapy is justifiable only when permission for amputation has not been given. Amputation for osteogenic sarcoma proximal to involved bone is advisable except when the lesion is located in the femur. He states that there were no five year cures in those cases in which there was involvement of the upper part of the femur and believes that an amputation through the upper portion of the thigh is indicated and justifiable when there is involvement of the lower part of the femur. Furthermore, he advocates interscapulothoracic disarticulation in those cases in which a tumor is located in the upper part of the humerus. He states that the prognosis for endothelioma is poor; Coley's mixed erysipelas and B prodigiosus toxins may help. Reticulum cell sarcoma of bone is radiosensitive, and perhaps immediate amputation is not necessary. Liposarcomas are somewhat radiosensitive, although amputation is necessary.

Martin [201] presents a discussion of roentgen treatment of tumors of bone and recognizes the limitation of this form of treatment. He gives data on 4 cases and concludes: "Irradiation therapy, although it seldom produces a complete cure, plays a very important role in the treatment of bone tumors, particularly those arising from the bone marrow and the lymphatic system."

Role of the Chemical Laboratory in Diagnosis of Neoplastic Disease of Bone.—Woodard [202] presents a review of the procedures for and the normal values of common laboratory tests used in diagnosis of tumors of bone and non-neoplastic diseases which may be confused with them. The procedures include determination of serum calcium, phosphorus (inorganic), protein and acid and alkaline serum phosphatase; a urinary test for Bence Jones protein, and the Sulkowitch test. She discusses differential diagnosis on the basis of chemical findings.

Experimental Study of the Effect of Estrogen.—Miller, Orr and Pybus [203] present a report on the effect of estrogen (estrone) on the skeleton of the mouse, with particular reference to the Newcastle bone tumor (NBT) strain. As a result of a sex difference in the incidence of spontaneous tumors of bone in the NBT strain (more in females than in males) estrone was administered to mice of this strain and to mice of three other strains with a low incidence of bone tumors. Bones of the hindlimbs of untreated NBT females showed, in general, quiescent hyperplasia, this being absent if oophorectomy had been done at an early age. Implantation of massive doses of estrone into young NBT males caused intense osteoclastic activity with some formation of bone; similar changes, but less complete, occurred in adult males; with smaller doses of estrone there were correspondingly less changes and more production of bone. Similar changes, but much less quantitatively, occurred in young males of other strains, which indicates some resistance to estrone. The induced lesions were reversible. Administration of estrone did not in itself give rise to sarcomas, but estrone is thought to be an adjuvant agent when the determining factor or factors are present.

[Ed. Note.—The grade of malignancy is an important factor in determining the prognosis and treatment of tumors of bone. There is an obvious need for more trained pathologists who

200. Coley, B. L.: Indications for Surgery in Bone Tumors, Texas State J. Med. **39**:290-293 (Sept.) 1943.

201. Martin, C. L.: X-Ray Treatment of Bone Tumors, Texas State J. Med. **39**:285-288 (Sept.) 1943.

202. Woodard, H. Q.: Role of the Chemical Laboratory in Diagnosis of Neoplastic Diseases of Bone, Arch. Surg. **47**:368-383 (Oct.) 1943.

203. Miller, E. W.; Orr, J. W., and Pybus, F. C.: The Effect of Estrone on the Mouse Skeleton, with Particular Reference to the Newcastle Bone Tumour (NBT) Strain, J. Path. & Bact. **55**:137-150 (April) 1943.

have made a special study of the interpretation of malignant lesions of bone. The evaluation of various methods of treatment should be correlated with the grade of malignancy (Broders). I do not believe that the results of treatment can be scientifically appraised unless the exact type and grade of malignancy have been determined in each case. The expert pathologist's opinion of the grade of malignancy in such instances is of the greatest aid to the surgeon.]

VI. CONDITIONS INVOLVING THE SHOULDER, NECK AND JAW

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Pathologic Conditions of the Shoulder.—In 1943 there were a number of papers which increased knowledge of the pathologic features of certain lesions about the shoulder.

Wilson [204] reviews the pathologic conditions of the tendinous attachments about the shoulder, particularly calcification and degeneration of the tendons. This paper gives a complete bibliography.

Wilson and Duff,[205] in a later paper, studied the gross and microscopic pathologic features of both shoulders in 90 adult bodies at autopsy and in 35 cadavers in the dissection room. All but 17 of the bodies were over 30 years of age. Complete rupture of the supraspinatus tendon was found in 9 of 34 cadavers. In the entire group, the incidence of complete rupture was 22.2 per cent with an average age of 65 years. They found that the frequency of rupture increased with age. A tear of the innermost fibers which included the joint capsule gave an apparent increase in the length of the tendon. A rupture of the tendon of the long head of the biceps muscle occurred in 7.4 per cent of the bodies. It frequently follows a rupture of the supraspinatus tendon. They believe that weakening of the supraspinatus tendon always precedes the rupture; a normal tendon does not rupture. Various degenerative lesions are described, which showed histologically alteration in the structure of the tendon, change in staining qualities, increase in the number of arterioles and alteration at the insertion of the tendon. The authors suggest that these degenerative changes are related to age and to injuries and occur in all parts of the body.

Lippmann [206] studied the pathologic changes in 12 "typical" cases of frozen shoulder at operation. He offers evidence to show that the chief lesion in so-called "periarthritis" of the shoulder is a bicipital tenosynovitis. This he believes to be the most common ailment in the region of the shoulder. The sheath of the long head of the biceps muscle is not a true sheath, in that it is closed only at one end, nor does the biceps tendon slide in its sheath. The greatest movement of the biceps tendon occurs in external rotation. The common cause of frozen shoulder or periarthritis is an inflammation in this sheath. When the inflammation subsides the tendon becomes fixed to the surrounding tissues, and pain subsides. The author found tenosynovitis of the tendon of the long head of the biceps muscle in every patient who was operated on. He believes that surgical operation is justifiable during the acute stage to obliterate the tendon sheath mechanism. To accomplish this the tendon should be sutured to the lesser tuberosity, with the arm in abduction and external rotation. Manipulation is not beneficial. Rest is suggested as the best treatment, since symptoms disappear if the tendon becomes fixed. The disability never recurs.

In the treatment of inflammation of the subdeltoid bursa, Brewer and Zink [207] suggest roentgen therapy as the best treatment of acute subdeltoid bursitis. A single dose of 300 r may suffice to relieve symptoms. This dose may be repeated if necessary in seven to ten days. Often there is an aggravation of pain for eight to twenty-four hours following radiation. The residual tenderness disappears in a few days. Of 14 patients 11 were completely relieved and returned to work in forty-eight hours. Radiation therapy was less effective for chronic bursitis. Only 30 per cent of the patients with chronic bursitis received benefit from the treatment. When no improvement occurs in forty-eight hours, the authors believe that operative treatment should be considered. The experience of Harris [208] is similar. He reports the results of treatment of 40 patients with acute subdeltoid bursitis with roentgen rays. Three or four treatments of 250 r were given daily. Relief of pain occurred in twenty-four to

204. Wilson, C. L.: Lesions of Supraspinatus Tendon: Degeneration, Rupture and Calcification, Arch. Surg. **46**:307-325 (March) 1943.

205. Wilson, C. L., and Duff, G. L.: Pathologic Study of Degeneration and Rupture of the Supraspinatus Tendon, Arch. Surg. **47**:121-135 (Aug.) 1943.

206. Lippmann, R. K.: Frozen Shoulder; Periarthritis; Bicipital Tenosynovitis, Arch. Surg. **47**:283-296 (Sept.) 1943.

207. Brewer, A. A., and Zink, O. C.: Radiation Treatment of Acute Subdeltoid Bursitis, J. A. M. A. **122**:800-801 (July 17) 1943.

208. Harris, J. H.: Roentgen Treatment of Acute Bursitis of Shoulder, Pennsylvania M. J. **46**:683-684 (April) 1943.

thirty-six hours. Normal use returned in about ten days.

[ED. NOTE.—Roentgen therapy for acute bursitis is useful, but in my experience this form of therapy alone brings relief of symptoms in only about a third of the patients treated. It must frequently be supplemented by other forms of therapy.]

Lapidus [209] reports the results of infiltration therapy in 34 patients with tendinitis with calcification. His technic was as follows: The tender spot over the tendon of the long head of the biceps brachii muscle was infiltrated with 10 to 20 cc. of a 1 per cent solution of procaine hydrochloride. The surrounding area was then infiltrated with 30 to 60 cc. of warm isotonic solution of sodium chloride after a roentgenogram showed that the needle was in the area of calcification. This method was used chiefly for tendinitis in the shoulder, but the author found it useful in other regions where inflammation of the tendon was present. Treatment was followed by relief of pain in twenty-four hours usually. After treatment there was gradual disappearance of the deposit. In cases in which there were adhesions or a "frozen shoulder," infiltration was of no value. It was also of questionable value for long-standing tendinitis.

Dislocation of the Shoulder.—Hale [210] believes that most dislocations of the shoulder can be reduced by bringing the arm over the head with traction parallel to the long axis of the body. Anesthesia is not usually necessary. For a short time after reduction a cuff is worn about the elbow to prevent wide abduction of the arm.

May [211] reports the use of the Nicola operation in 3 cases of posterior dislocation of the humeral head. The procedure was successful in 2 of them. In the other the proximal end of the long head of the biceps muscle became stretched. The redislocation was repaired by a fascial sling.

A review of the tenosuspension operation for recurrent dislocation of the shoulder is presented by Henderson.[212] Fifty-five operations were performed on 51 patients. The peroneus longus tendon is split, and half of the tendon is removed for the tenosuspension. The patients remain in bed ten days after operation, when physical therapy is begun. Ninety-one per cent of the patients were cured by this operation. Five patients had dislocations subsequent to the operation. Three of these were subject to epilepsy and in 2 the tendon was too short. If the dislocation is going to recur, it will take place within one year of operation.

Other Conditions About the Shoulder.—Oppenheimer [213] believes that arthritis of the acromioclavicular joint is fairly common. It is demonstrated most easily in roentgenograms showing anteroposterior views, with the patient upright and holding the shoulder back. The symptoms are indistinguishable from those of other lesions in this region. Roentgen therapy, in small doses, is an effective method of treatment.

[ED. NOTE.—Evidence of arthritic involvement of this joint is frequently seen in roentgenograms. Symptoms are not often found. In most instances it is merely incidental.]

Mazet [214] reports 2 cases in which a Kirschner wire migrated from the shoulder region into the lung. In the first case it followed the insertion of two Kirschner wires for the repair of an acromioclavicular dislocation. Three months later the wire had become embedded in the upper lobe of the right lung. There were no symptoms. The wires were removed, and there were no sequelae. In the second case a shoulder paralyzed from poliomyelitis was fused and three Kirschner wires were drilled through the humeral head into the glenoid. Two months later two wires were removed. The third wire had migrated into the thoracic cavity. It was removed without complication. The author advises using a stop or a nut on Kirschner wires to prevent migration.

Forty-six cases of localized neuritis of the shoulder girdle are reported by Spillane,[215] which he observed while serving as medical officer with the troops in the Middle East. In 26 the neuritis was associated with various afebrile conditions. In 20 it developed while the patient was in the field. Sharp pains in the shoulder were the first symptom in 42. Weakness in muscles followed in four to five days. This weakness was followed by atrophy. In none of the cases did complete recovery occur.

209. Lapidus, P. W.: Infiltration Therapy of Acute Tendinitis with Calcification, Surg., Gynec. & Obst. **76**:715-725 (June) 1943.

210. Hale, K.: French Method of Reducing Subluxation of the Shoulder, Ohio State M. J. **39**:1006-1007 (Nov.) 1943.

211. May, H.: Nicola Operation for Posterior Subacromial Dislocation of the Humerus, J. Bone & Joint Surg. **25**:78-84 (Jan.) 1943.

212. Henderson, M. S.: Tenosuspension Operation for Recurrent or Habitual Dislocation of the Shoulder, S. Clin. North America **23**:927-945 (Aug.) 1943.

213. Oppenheimer, A.: Arthritis of Acromioclavicular Joint, J. Bone & Joint Surg. **25**:867-870 (Oct.) 1943.

214. Mazet, R., Jr.: Migration of Kirschner Wire from Shoulder Region into Lung: Report of Two Cases, J. Bone & Joint Surg. **25**:477-483 (April) 1943.

215. Spillane, J. D.: Localized Neuritis of the Shoulder Girdle: A Report of Forty-Six Cases in the M. E. F., Lancet **2**:532-535 (Oct. 30) 1943.

The serratus anterior muscle was involved in 34 cases, the spinatus muscles in 24, the deltoid muscle in 17 and the trapezius muscle in 11. Other muscles were rarely involved. The nerve lesion was peripheral. Various forms of treatment were employed without success. The cause of the neuritis was unknown.

Dynes [216] observed 2 patients in whom subacromial bursitis developed after the onset of disease of the nervous system without trauma. The first patient was suffering from hemiplegia and the second from Parkinson's disease. Response to treatment of the bursitis was slow, and full recovery did not occur.

The Neck.—Semmes and Murphey [217] report 4 cases of unilateral rupture of the sixth cervical intervertebral disk with compression of the seventh cervical nerve root. Three of the patients were men, and 1 was a woman. The duration of symptoms varied from three weeks to seven years. There was a history of numerous catches in the neck preceding pain along the seventh cervical nerve, difficulty in breathing and muscular spasm in the neck. There was tenderness over the root of the seventh cervical nerve. Roentgenograms showed straightening of the cervical portion of the spine. In 1 patient there were narrowing of the intervertebral foramen and lipping. No contrast medium was used in the roentgenographic studies. Operation was performed, with the area under local anesthesia. The protruded disk was small. The total protein content of the spinal fluid was increased in 2 patients. Three patients were operated on; 2 were completely relieved, and 1 had slight persistent pain but was improving with physical therapy. The authors believe that the diagnosis of this condition is often missed and that it is confused with osteoarthritis. They do not think that osteoarthritis produces symptoms in the nerve roots.

A critical discussion of the various hypotheses of the mechanisms causing infringement on cervical nerve roots is given by Hanflig.[218] Methods of diagnosis are described. He outlines his method of traction, maintained with 5 or 10 pounds' (2.3 or 4.5 Kg.) weight on the cervical portion of the spine.

Two patients with atlantoaxial dislocation are described by Bull.[219] The first patient was a 60 year old laborer, who complained of difficulty in using his arms and inability to walk following an electric shock one month before. Roentgenograms showed an anterior dislocation of the atlas on the axis with fracture of the odontoid peg. Traction was applied to the neck, after which a Thomas neck splint was used. Symptoms were partially relieved, but improvement was lost when the splint was discarded. The other patient was unable to use his arms and legs. There was dislocation of the axis on the atlas but no fracture of the odontoid peg. No treatment was given.

Intermittent compression of the subclavian artery and vein between the clavicle and the first rib was found in 3 patients by Falconer and Weddell.[220] These patients were examined to determine the effects of postural maneuvers of the shoulder girdle on the pulse. Backward and downward bracing of the shoulders obliterated the pulse readily. The authors found that the pulse in the subclavin vessels could be obliterated by such maneuvers in many normal persons. Symptoms arose only when compression took place easily. This disability was differentiated from the scalenus anticus syndrome by paralyzing the scalenus anticus muscle with a local anesthetic. A fourth patient was found with neurologic symptoms only following such compression. For patients with the milder symptoms remedial exercises to improve the postural tone in the muscles of the shoulder girdle were of benefit. Those with more severe symptoms required operation. This consisted of removal of a segment of the offending rib.

Engel [221] attempts to apply Bonnevie's theory, that pressure from a cerebrospinal fluid bleb is responsible for the development of deformities, to the development of undescended scapula, Klippel-Feil syndrome and symbrachydactylia. He postulates the escape of cerebrospinal fluid through the area membranacea of the fourth ventricle at the time the limb buds for the upper extremities are beginning to appear. From pressure of such cerebrospinal blebs, destruction or delay in development could result in the limb bud and in the spinal column as well. He cites

216. Dynes, J. B.: Subacromial Bursitis Associated with Diseases of the Nervous System, Lahey Clin. Bull. **3**:124-127 (April) 1943.

217. Semmes, R. E., and Murphey, F.: Syndrome of Unilateral Rupture of Sixth Cervical Intervertebral Disk, with Compression of Seventh Cervical Nerve Root, J. A. M. A. **121**:1209-1214 (April 10) 1943.

218. Hanflig, S. S.: Pain in the Shoulder Girdle, Arm and Precordium Due to Foraminal Compression of Nerve Roots, Arch. Surg. **46**:652-663 (May) 1943.

219. Bull, G. M.: Syndrome of Atlanto-Axial Dislocation, Clin. Proc. **1**:336-345 (Oct.) 1942.

220. Falconer, M. A., and Weddell, G.: Costoclavicular Compression of Subclavian Artery and Vein, Lancet **2**:539-543 (Oct. 30) 1943.

221. Engel, D.: Etiology of Undescended Scapula and Related Syndromes, J. Bone & Joint Surg. **25**:613-625 (July) 1943.

experiments by others in which claw foot, claw hand and polydactylism resulted from similar pressure.

[Ed. Note.—This is an interesting and intriguing speculation. Much more work must be done to make it a convincing argument.]

The Jaw.—Brown and McDowell [222] have found that Kirschner or stainless steel wires drilled through the jaw are helpful in the fixation of fractures of the jaw which cannot be held by interdental wiring. This method is particularly useful in compound fractures, fractures at the angle of the jaw and fractures where there are no teeth for wiring. Since one wire fixes the bones in one plane only, several wires are usually required. In their cases the wires were drilled into the mandible with a power drill. There was little reaction from the wires. Sulfonamide drugs were used locally. The bones were alined by hand and then fixed with the wires. The nerve canal was carefully avoided. The patient remained in the hospital two to three days. The wires were usually removed in three to five weeks.

[Ed. Note (L. D. B.).—The use of internal fixation in compound fractures may be disastrous, if the nerve canal is not avoided the involved teeth will be killed.]

Smith [223] describes an operation for recurrent dislocation of the jaw. A 1 inch (2.5 cm.) vertical incision is made anterior to the external meatus of the ear. This leaves little scar. A speculum is introduced through this incision and pushed inward until it touches the tuberculum articulare. A 9/64 inch (0.35 cm.) drill is introduced through the speculum and directed cephalad at a 45 degree angle. A bone peg 10/64 inch (0.39 cm.) in diameter is then screwed into the previously drilled hole and left projecting 1/4 inch (0.64 cm.) beyond the tuberculum articulare. This acts as a buffer for the condyloid process. Temporary weakness of the facial nerve sometimes occurs.

The facial bones of 2 men with Paget's disease were studied by Glickman.[224] In 1 patient the disease was found in the right maxilla only. In the other it was found in the maxilla, the mandible and the palatine bones. The changes were like those found in other parts of the body in which Paget's disease was present—areas of degeneration, formation and resorption of bone distributed irregularly in close proximity to each other. There was no characteristic picture which could be identified as Paget's disease. Diagnosis could be made only by studying all of the changes in the bone.

222. Brown, J. B., and McDowell, F.: Internal Wire Fixation for Fractures of the Jaw: Preliminary Report, Am. J. Orthodontics (Oral Surg. Sect.) **29**:86-91 (Feb.) 1943.

223. Smith, L. D.: Operation for Correction of Recurrent Dislocation of the Jaw, Arch. Surg. **46**:762-763 (May) 1943.

224. Glickman, I.: Paget's Disease in Maxilla, Mandible and Palate, Am. J. Orthodontics (Oral Surg. Sect.) **29**:591-607 (Nov.) 1943.

(To Be Continued)